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Uranium From the Chattanooga Shale

Some Problems Involved in Development

UNITED STATES DEPARTMENT OF THE INTERIOR

U.S. Bureau of Mines,

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Uranium From the Chattanooga Shale

Some Problems Involved in Development

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UNITED STATES DEPARTMENT OF THE INTERIOR
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URANIUM FROM THE CHATTANOOGA SHALE

Some Problems Involved in Development

by

P. H. Mutschler,[1] J. J. Hill,[2]
and B. B. Williams[2]

ABSTRACT

The Bureau of Mines studied the Chattanooga Shale to determine the quantity and quality of the uranium resources present and to assess specific environmental effects of mining the shale.

Geologic data and chemical analyses, mainly concerning a 12-county area of Tennessee, were compiled from previous published and unpublished reports. Uranium resources in the Gassaway Member of the Chattanooga Shale in this 12-county area were estimated to be between 4.2 and 5.1 million tons, contained in 76 to 91 billion tons of shale. These figures represent inground tonnages and do not allow for mining or processing losses. Depending upon efficiency of mining and processing systems, enough uranium could be available to satisfy a large part of the cumulative domestic and world demand through the year 2000.

A model was developed which assesses the total tons or acres of shale to be mined if the Gassaway Member were to satisfy 1 percent of the United States demand for uranium in 1991. This partially demonstrates the environmental impact of mining the shale and is easily factorable to any specified demand.

INTRODUCTION

The Chattanooga Shale, a low-grade source of uranium, is a unit of uraniferous black marine shale that extends with fairly uniform thickness and lithology over a large area in the East Central United States. Although the uranium content of the shale is low in comparison with high-grade western sandstone deposits, reserves of the higher grade ores are diminishing. Consequently, the Chattanooga Shale which contains the largest known source of uranium in the United States is receiving increased attention.

The Federal Bureau of Mines has a mandated interest in the conservation and utilization of energy. Uranium as a fuel for powerplants is projected to be in short supply due to significant increases in future demand.

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[1]Industry economist.
[2]Geologist.

This study was done at the request of Salt Lake City Metallurgical Research Center, Bureau of Mines, and investigates the impact that the Chattanooga Shale could have in partially alleviating future domestic uranium supply problems along with defining areas for needed future work on the shale.

Data from previous field studies pertaining to the reserve potential of the shale have been aggregated and the locations for which a mean uranium content can be determined have been plotted on maps within this report. Experts from mining companies, universities, and State and Federal agencies were interviewed to assess their impressions of the potential impact mining the Chattanooga Shale would have on uranium supply and the environment.

Generally, analytical data developed for previous reports, both published and unpublished, were from reconnaissance investigations over broad areas or in-depth analyses of specific areas. This report attempts to collectively appraise all previously generated analytical data on the Chattanooga Shale for for an area in Kentucky, Tennessee, Alabama, and Georgia.

ACKNOWLEDGMENTS

Special mention is accorded to Mr. William D. Hardeman, Federal Bureau of Mines Liaison Officer, Nashville, Tenn., for providing helpful suggestions and information pertinent to the completion of this study. Mr. Warren I. Finch, Chief, Branch of Uranium and Thorium Resources of the U.S. Geological Survey, Denver, Colo., cooperated by making unpublished data by other U.S. Geological Survey personnel available for this study. Dr. Harry J. Klepser, Department of Geology, University of Tennessee, Knoxville, Tenn., also contributed some unpublished geologic data.

AREA OF STUDY

This report examines an area encompassing approximately 35,000 square miles in south-central Kentucky, central Tennessee, northeastern Alabama, and northwestern Georgia (fig. 1). Areal boundaries have been established to define the limits of concentrated geologic and engineering data available on the Chattanooga Shale. These data result from field investigations conducted from 1944 through 1959 mainly by the U.S. Geological Survey, the Federal Bureau of Mines, and the University of Tennessee.

PREVIOUS INVESTIGATIONS

Reconnaissance investigations of the Chattanooga Shale for uranium were first conducted in 1944 by the U.S. Geological Survey for the Manhattan Engineer District (12, 16).[3] Radiometric readings supplemented by a few chemical assays were used to determine the uranium content of scattered black shale outcrops within Tennessee, Kentucky, Ohio, and Indiana. Knowledge gained from these preliminary studies indicated the Chattanooga Shale was more radioactive than other rocks existing in much of the Eastern and Central United States.

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[3] Underlined numbers in parentheses refer to items in the list of references on p. 38 of this report.

FIGURE 1

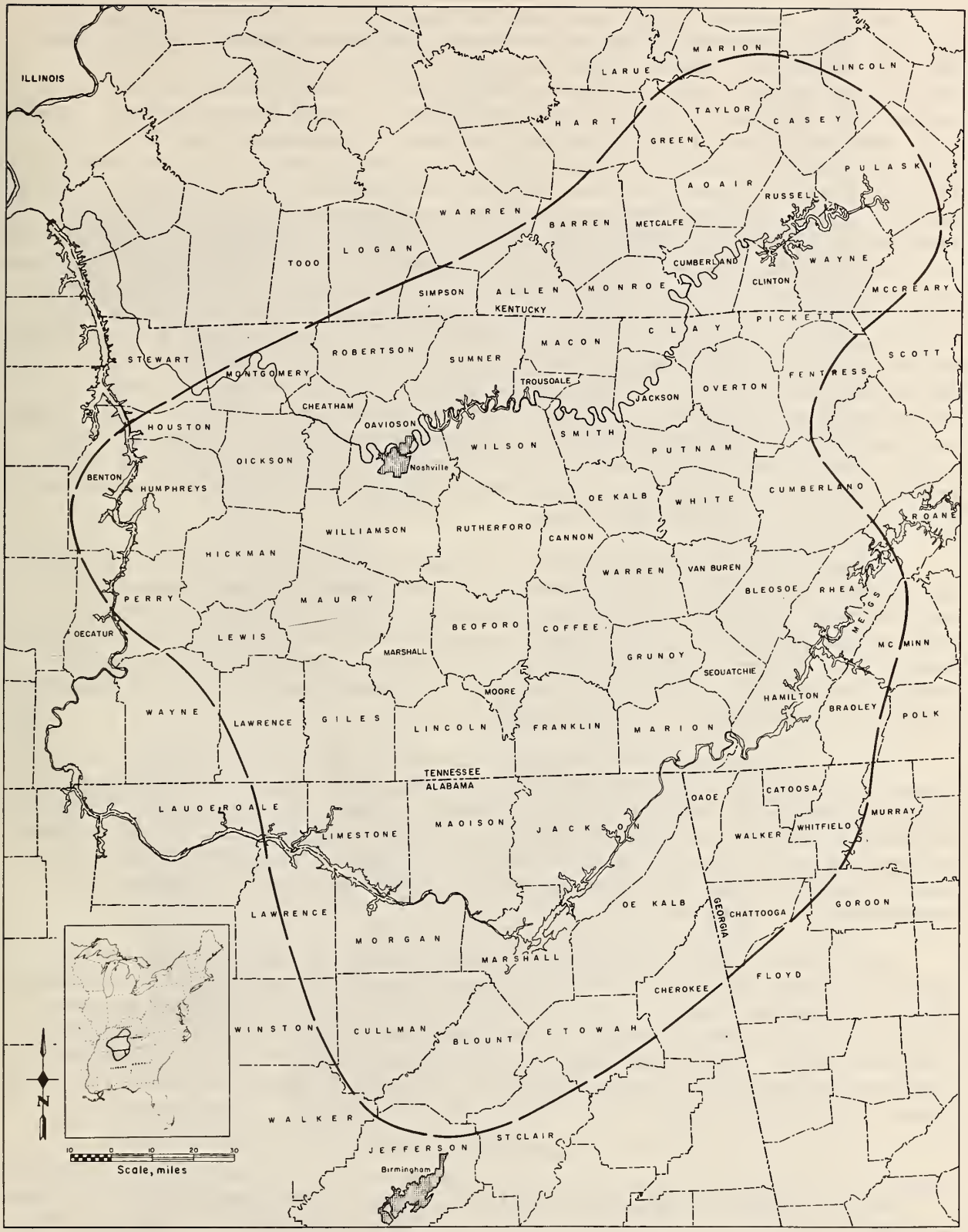

FIGURE 1. - Chattanooga Shale study area.

In 1947, at the request and with the support of the Atomic Energy Commission (AEC), now the Energy Research and Development Administration (ERDA), the U.S. Geological Survey began intensive field investigations of the Chattanooga Shale. This program was designed to develop more precise information with detailed geologic study and chemical assay determinations. Field work started in the Eastern Highland Rim area of Tennessee (fig. 2) and by 1948, had extended to the eastern side of the Sequatchie Valley and vicinity. At that time, a limited drilling program was instituted to supplement outcrop sampling and a 100-foot adit was driven in DeKalb County to provide large samples of unweathered shale. As sampling progressed throughout Tennessee and into neighboring States, studies were directed toward evaluating oil yield as well as uranium content. Regions within Tennessee were divided into seven blocks for ease in mapping and reporting procedures (fig. 3). By the mid-1950's, several higher grade uranium deposits had been discovered, principally on the Colorado Plateau and in the Wyoming basins, and interest in the Chattanooga Shale as a low-grade uranium source waned. Uranium assay determinations of samples from about 250 outcrops and a number of drill cores had been made. During this period, numerous Trace Element Investigations (TEI) reports were issued by the U.S. Geological Survey, summarizing the results of their studies; most of these results were subsequently published as bulletins and professional papers.

Although the U.S. Geological Survey did much of the investigative work, the Bureau of Mines and the University of Tennessee also made substantive contributions. Late in 1952, an extensive diamond drilling program to confirm analytical and stratigraphic data was started in Tennessee through a cooperative agreement between the Bureau of Mines and the U.S. Geological Survey for the AEC. Sixty-one core holes in Tennessee and three in Alabama were drilled during the 1-year program.

In conjunction with governmental investigations, the University of Tennessee, under AEC contract, conducted a detailed study of the Chattanooga Shale with emphasis on stratigraphic relationships. As the program progressed, however, attention was also directed toward the determination of the amounts of uranium and oil present in the shale. Between 1951 and 1959, 420 lithologic logs were prepared; samples from 123 localities were collected for uranium and oil analyses.

While field investigations were being conducted, the Division of Raw Materials, AEC, sponsored several research projects concerned with geochemical and mineralogical examination of the Chattanooga Shale. Battelle Memorial Institute and Columbia University both examined methods of uranium recovery from the shale. Mineralogic and petrographic studies of black shales and lignites, with specific emphasis on the Chattanooga Shale, were undertaken by Pennsylvania State University.

GEOLOGIC SETTING

Structurally, the Nashville Basin of central Tennessee is part of a broad truncated dome on the Cincinnati arch extending northward into Kentucky and southward into Alabama. Exposed rocks of the region range in age from

FIGURE 2

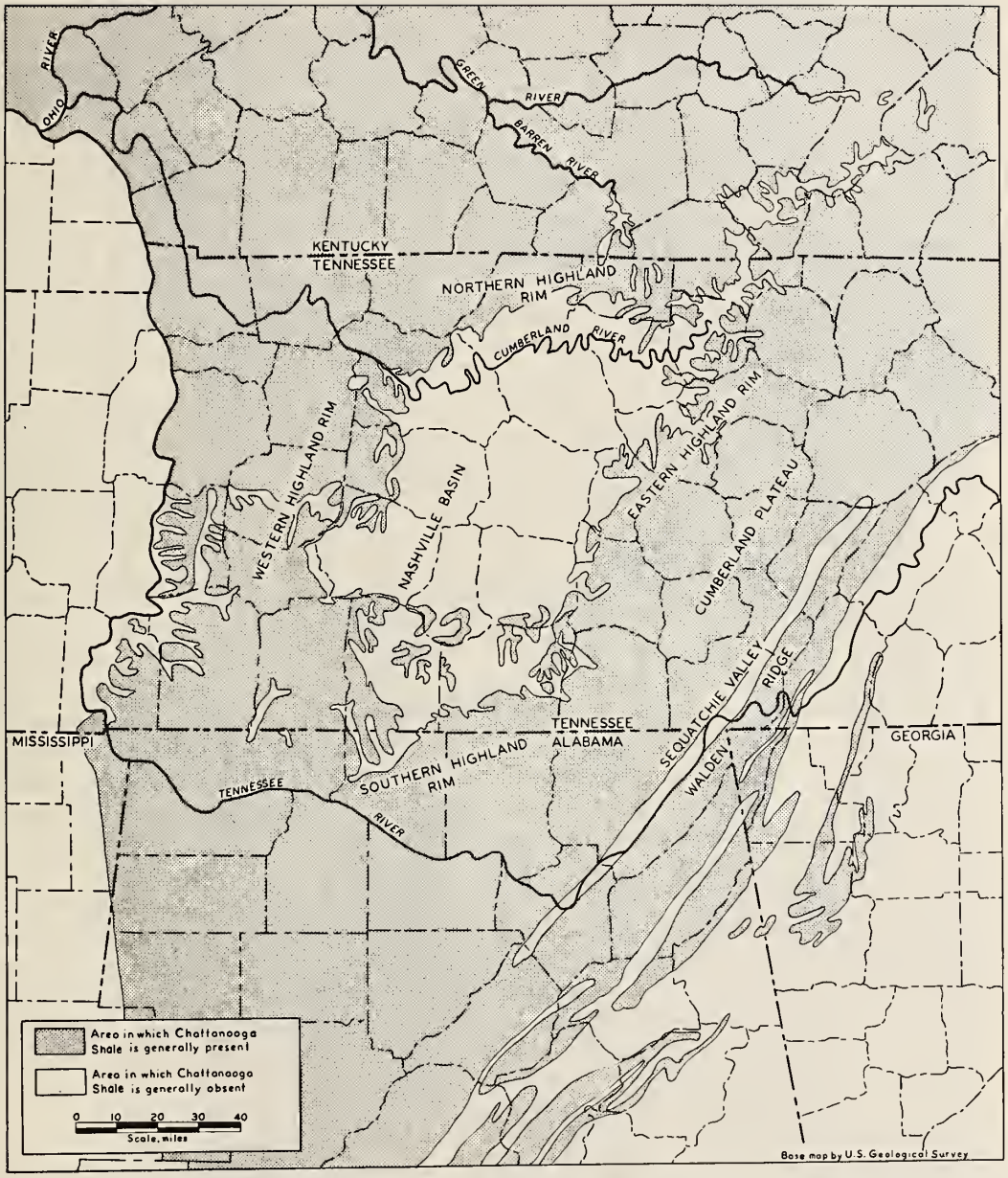

FIGURE 2. - Areal extent of the Chattanooga Shale in Tennessee and adjacent areas. (Adapted from Conant and Swanson (11); plate from Hickman and Lynch (18).)

FIGURE 3

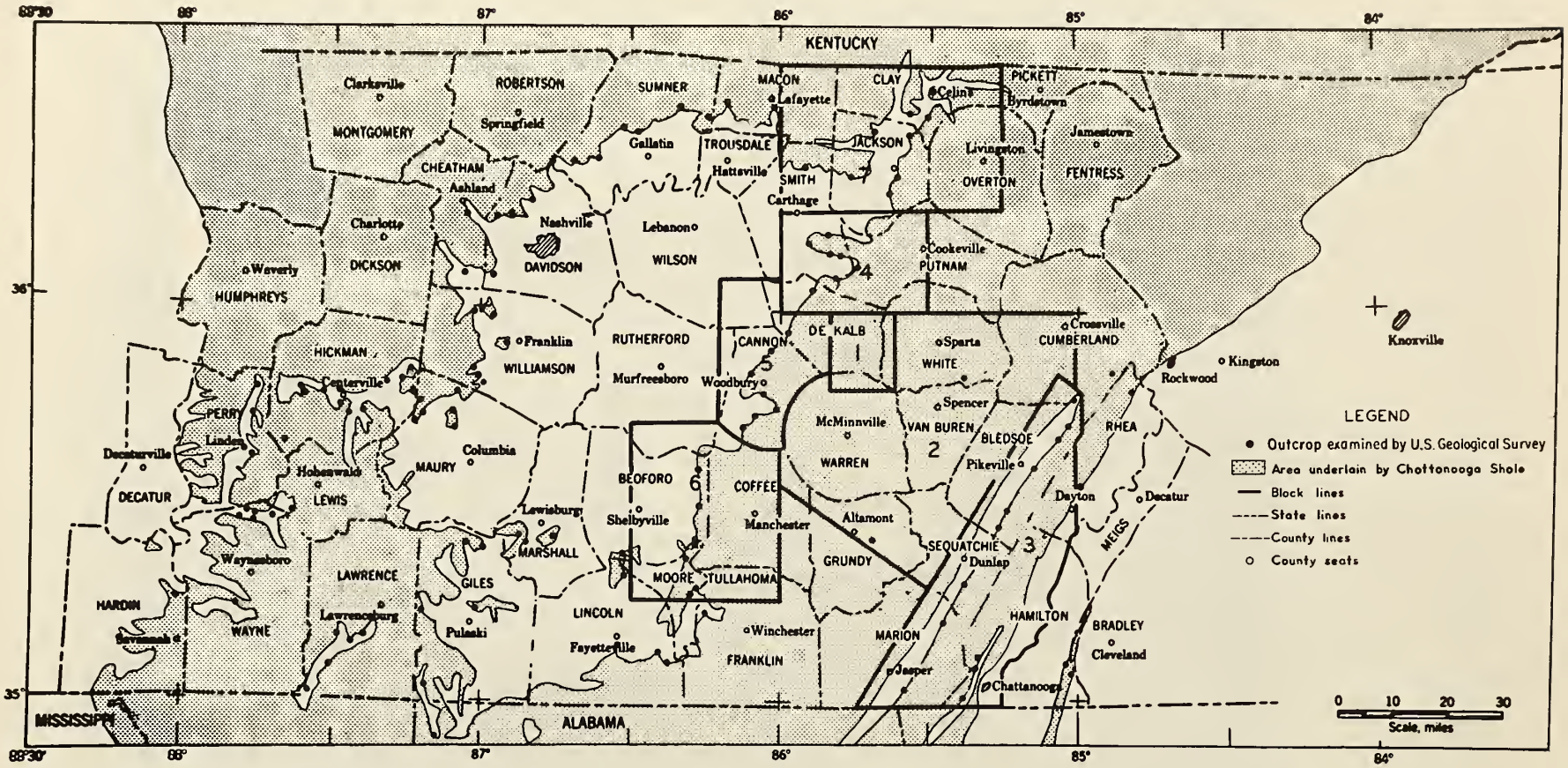

FIGURE 3. - U.S. Geological Survey reference blocks. (Adapted from Conant and Swanson (11); plate from Hickman and Lynch (18).)

Ordovician to Cretaceous and generally dip away from the dome's former crest at a rate of 10 to 15 feet per mile. As a result of the Appalachian Orogeny, older rocks are exposed in the southeastern portion of the study area which has been intensely folded and faulted and is characterized by steeply dipping beds.

Physiography (12)

The study area lies primarily within three physiographic provinces: the Nashville Basin, the Highland Rim, and the Cumberland Plateau. Figure 2 shows the generalized areal extent of the Chattanooga Shale and identifies the provinces.

Topographically, the Nashville Basin is a lowland occupying the crestal area of the truncated Nashville dome. Ordovician limestones form the undulating floor of the basin, 400 to 500 feet above sea level. Differential weathering between a cap of resistant chert and the underlying, less resistant units has resulted in a 300- to 500-foot escarpment at the edge of the basin. The Chattanooga Shale, which once covered the area of the present basin, is exposed in the upper part of the escarpment.

The Highland Rim is comprised of those upland areas approximately 1,000 feet above sea level which surround the Nashville Basin and is subdivided into four geographic regions. The Chattanooga Shale generally underlies the entire province except where streams have cut so deeply as to erode the shale.

The Cumberland Plateau trends in a northeast-southwest direction and adjoins the Eastern Highland Rim in Tennessee and the Southern Highland Rim in Alabama. The plateau rises nearly 1,000 feet above the gentle topography of the eastern rim. To the south, this change in elevation is somewhat less. The Chattanooga Shale is continuous under the general plateau surface until interrupted by the Sequatchie Valley, a topographic depression along the breached axis of the Sequatchie anticline. Shale is not exposed on the western side of the valley due to fault displacement but does crop out on the eastern side (the western slopes of Walden Ridge).

The Appalachian Valley and Ridge province lies immediately east of the Cumberland Plateau and scattered outcrops of the Chattanooga Shale are present on flanks of some of the Appalachian folds. The shale has been subjected to intense orogenic forces and in many places has been removed by erosion. Within this region, available geologic information prohibits a quantitative appraisal of the shale's resource potential at this time.

Stratigraphy (12)

The Chattanooga Shale is part of a sequence of Late Devonian to Early Mississippian black shales which cover most of the East-Central United States and extend northwesterly into Canada. Stratigraphic equivalents or partial equivalents include the New Albany, Mountain Glen, Antrim, Ohio, Woodford, and Three Forks shales.

FIGURE 4

FORMATION (THICKNESS IN FEET)	MEMBER		SECTION	THICKNESS IN FEET	CHARACTER OF ROCKS
Fart Payne Chert 200±				200+	Interbedded chert and limestone; greenish-gray to grayish-yellow bedded chert and greenish-gray dense argillaceous siliceous limestone.
Maury Farmatian 2.3				1.9±	Claystone and scattered phosphate. Claystone is light to medium bluish gray (fresh), grayish yellow green to dark yellowish orange (weathered); has blocky to subconchoidal fracture. Phosphate in form of balls, disks, and plates; balls and disks less than 0.1 foot in diameter; plates less than 0.5 foot in greatest dimension; most abundant at top and base. Top contact is sharp and undulating having 0.1-foot relief.
Chattanaaga Shale 32.1	Gassaway Member	Upper		0.4±	Phosphate nodule layer of variable thickness. Nodules of many shapes as much as 1.5 feet or more in greatest dimension, in an olive-gray sandy matrix. Concentration of nodules varies laterally. Where nodule layer is thickest, overlying claystone is correspondingly thinner.
				6.9	Black shale. Scattered phosphate nodules in upper 0.4 foot. Unweathered rock is grayish black, massive, and breaks with conchoidal fracture; weathered rock is medium to dark gray and finely fissile. Paper-thin medium dark-gray siltstone partings; films and thin lenses of marcasite.
		Middle		2.3	Interbedded black shale and medium-gray claystone. Chiefly black shale as described in overlying unit. At base is a "varved bed" approximately 0.05 to 0.20 foot thick consisting of thin alternating beds of light-brown siltstone and black shale; the black shale layers become thicker and more closely spaced upward. Basal contact sharp.
		Lower		7.5	Black shale. Similar to 6.9-foot black shale unit above. A few thin layers of medium-gray claystone near base, suggesting that lower contact is gradational.
	Dowellttown Member	Upper			Center Hill bentonite bed.
				9.2	Interbedded medium light-gray claystone and dark-gray shale beds commonly 0.1 to 0.4 foot thick. Bentonite bed, 0.09 foot thick, has conspicuous biotite flakes; olive gray where fresh, pale yellowish orange where weathered and readily observed on face of outcrop; top is 0.85 foot below top of unit.
		Lower		6.2	Black shale. Generally resembles 6.9-foot shale unit above, color ranging from grayish black to dark gray. Poorly sorted basal sandstone present at most places. Averages about 0.02 foot thick; contains very fine grained clear quartz, iron sulfide, waterworn chert and shell fragments, and conodonts. Basal contact sharp but slightly undulating, truncating underlying limestone at an angle of 1° or less.
					Unconformity
Leipers Limestane 50±					Limestone, bluish-gray, and argillaceous; light-gray to bluish-gray calcareous siltstone in lower 30 feet. Weathers grayish orange to yellowish gray.

FIGURE 4. - Stratigraphic section of the Chattanooga Shale in DeKalb County, Tenn. (Adapted from Conant and Swanson (12).)

Throughout most of the study area considered in this report, the Chattanooga Shale is about 30 feet thick. The formation is Late Devonian in age and unconformably overlies formations ranging in age from Devonian to Ordovician. For purposes of this report, the shale is divided into two separate members, the Gassaway and the Dowelltown (fig. 4). A basal member, the Hardin Sandstone, is present in Wayne County, Tenn., and in parts of adjoining counties of Tennessee and Alabama. Due to this limited areal extent, the Hardin is not considered even though it is formally recognized as a member of the Chattanooga Shale.

The Gassaway Member, the upper portion of the formation, is a massive black shale except for a 2- to 3-foot middle unit of interbedded black shale and gray claystone present throughout the Eastern Highland Rim and parts of the Cumberland Plateau. Locally, in northern Tennessee and into Kentucky, the uppermost beds of the member contain phosphatic nodules occurring either in zones or scattered randomly throughout the shale.

The Dowelltown Member is generally less massive than the Gassaway Member and is divided into two lithologic units: A lower unit of black shale similar to that of the Upper Gassaway, and an upper unit of gray claystone interbedded with black shale.

Immediately above the Gassaway Member of the Chattanooga Shale lies the Maury Formation, commonly 1 to 4 feet thick. The base of the formation is considered to be either latest Devonian or earliest Mississippian in age.

Above the Maury Formation is the resistant Fort Payne Chert, a 200-foot unit of Mississippian age. A stratigraphic equivalent, the less resistant New Providence Shale (also referred to as the Ridgetop Shale) is present in most of Kentucky and parts of northern Tennessee.

ANALYTICAL DATA BASE

A large amount of chemical analytical data (predominantly uranium analyses) exists for the Gassaway Member of the Chattanooga Shale. Data for the Dowelltown Member are comparatively sparse, reflecting early investigations that showed the Gassaway Member contained nearly twice as much uranium as the Dowelltown. Analyses from 222 localities which contribute to an engineering evaluation of the Gassaway Member with respect to tonnage and grade have been aggregated and compiled as a data base for this report.

A weighted mean uranium content for the Gassaway Member from each locality is presented in table A-1, appendix A. Tabulated also are the weighted mean oil yields reported for 34 localities. Where available for the same 222 localities, weighted means of uranium content and oil yield for the Dowelltown Member and the Maury Formation are presented in table A-2.

Appendix B contains analyses from geochemical and mineralogical studies conducted after field investigations had ended. Weighted mean values could not be determined for the data contained in table B-1 and percentages shown represent unweighted average values. Standard deviations have been included to show the variance between individual sample analyses.

Distribution of Data

Figures A-1 and A-2, appendix A, show the localities (149 outcrops and 73 drill sites) from which a weighted mean uranium content of the Gassaway Member has been determined (see table A-1). DeKalb County, Tenn. (fig. A-2), has the greatest concentration of drill and outcrop data and appears as a separate figure for illustrative purposes. Sites related to the data presented in appendix B are identified in figure B-1.

Data Limitations

Data presented in appendices A and B summarizing information developed over a period of several decades have the limitations and constraints which were placed on the original studies and the data contained therein. General difficulties encountered with the data include: (1) Location description; (2) effects of weathering; and (3) conflicts among different investigative parties.

In this study, outcrop and drill-hole locations were derived from both published and unpublished sources. Location descriptions of sample sites vary in detail and conflict in some instances. Many of the original investigations were carried on before detailed topographic maps on the present scale were available, perhaps contributing to variations in location descriptions. All localities cited in table A-1 were plotted on U.S. Geological Survey 7-1/2-minute topographic quadrangle maps and Universal Transverse Mercator (UTM) grid coordinates determined to the nearest 100 meters. In the few instances of conflict (generally outcrop locations), the plausibility of the specific location was verified with 7-1/2-minute quadrangle geologic maps published by the Division of Geology, State of Tennessee.

Early investigators questioned the reliability of analyses from outcrops due to the effects of weathering. Deeply weathered outcrop samples of the Chattanooga Shale may contain from 20 to 40 ppm more or less uranium than a fresh sample from the same unit; further, there is lower oil yield from weathered shale due to the breakdown of organic matter by oxidation (27, p. 7; 29). Efforts were made by early field investigators to obtain the freshest samples possible from outcrops. The effect of weathering could not be weighed in the tabulation of analyses contained in this report.

Analyses tabulated in this report are from the latest dated source available, as accuracy of determinations has improved through the years and several samples have been reanalyzed by later investigators. Most analyses are reported to be within ±5 parts per million (ppm).

Conflicting data were noted in early reports concerning the stratigraphic placement of phosphatic zones, whether they belonged in the Gassaway Member or within the Maury Formation. Thicknesses of the units reported in appendices A and B are from the latest dated sources available for this compilation. In the few instances where different investigative parties measured the same outcrop and reported conflicting data, the thicknesses reported by the U.S. Geological Survey were used.

DATA ANALYSIS

From the data presented in this report, tenable conclusions may be drawn on the thickness of units and distribution of constituents within the Chattanooga Shale which relate directly to the economic potential of the formation. In particular instances, however, existing data are too scattered geographically to justify extrapolation or to permit reliable interpretation of distribution patterns.

Extent and Thickness of Units

The Gassaway Member has the greatest areal extent of any unit in the Chattanooga Shale. A mean ($\bar{x}$) thickness of the 222 localities (table A-1) is 14.73 feet. This is somewhat lower than reported average thickness values of previous reports and may reflect the fact that a number of measurements were taken in areas where the shale thins to extinction.

In the Eastern Highland Rim area the member achieves thicknesses between 17 and 21 feet (figs. 5 and 6). From this area the unit thins gradually westward toward the eastern edge of the Nashville Basin where thickness values are commonly 11 to 13 feet.

Further east, in the Walden Ridge area, the member ranges between 11 and 21 feet in thickness. Along Walden Ridge, as well as in the Eastern Highland Rim, the Gassaway generally thickens northward.

The thickness of the Gassaway Member along the Northern Rim of the Nashville Basin averages 15 to 16 feet and increases to the north into Kentucky (12). Thicknesses in eastern Sumner County are consistently 16 feet but are thin to the southwest in the direction of Nashville where they are about 10 to 12 feet.

In Tennessee, the Gassaway Member is generally thinnest in regions south of the basin. In southwestern portions of the Highland Rim, the member is about 6 feet thick at the basin's edge and thins to extinction in Lawrence and adjoining counties. In the southeast, thinning continues southward to an area approximately parallel to the Tennessee-Alabama State line. In this southernmost area of investigation, primarily in northern Alabama and northwestern Georgia, stratigraphic recognition of units within the formation is questionable. While one report (12, p. 35) indicates Gassaway thicknesses ranging from 0 to 40 feet generally constitute the entire section of Chattanooga Shale, others (16, p. 12; 6, p. 24) state that only the upper units of the black shale present are Gassaway and that the lower beds are of Dowelltown age. Additional geologic work is needed in this area as existing information is from widely scattered localities, and thicknesses believed to represent the entire formation vary considerably within distances of several miles.

Zones of scattered phosphate nodules within the Gassaway are present in some parts of the northern portions of the Eastern Highland Rim and Walden Ridge. Zone thicknesses generally range from 0 to 4 feet. This is of note because the shales containing phosphate nodules generally have a lower uranium content than those not containing nodules (12).

FIGURE 5

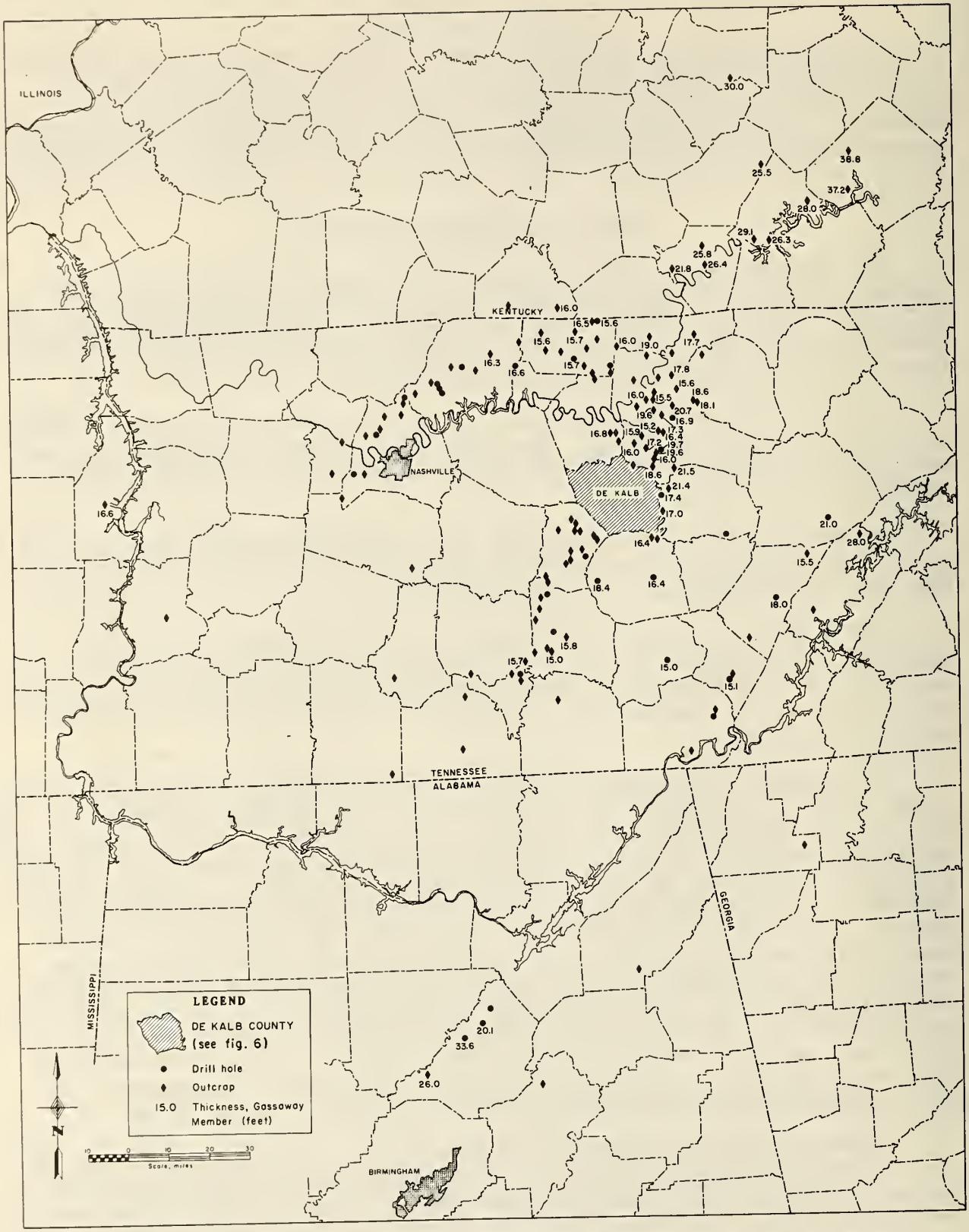

FIGURE 5. - Sample localities where thicknesses of the Gassaway Member are greater than 15 feet.

FIGURE 6

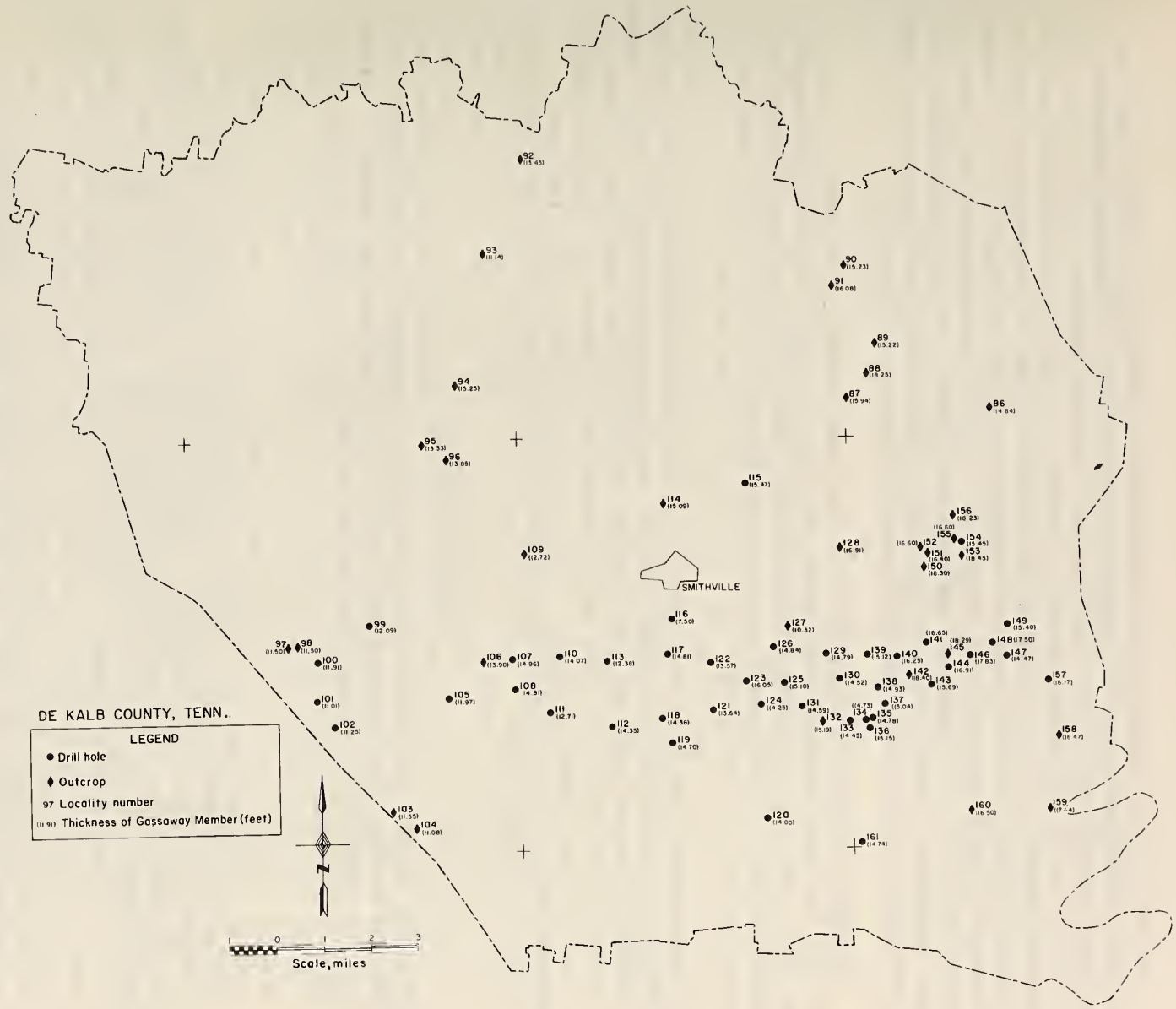

FIGURE 6. - Thicknesses of the Gassaway Member at sample localities in DeKalb County, Tenn.

The Dowelltown Member, although absent in the whole southwest quadrant, is present throughout most of the Eastern and Northern Highland Rim areas. A mean ($\bar{x}$) of the 96 Dowelltown thicknesses included in this report (table A-2, appendix A) is 13.02 feet. However, sections in the central part of the Eastern Highland Rim are nearly 20 feet thick (26). Thicknesses in portions of DeKalb, Cannon, Coffee, Warren, and White Counties average over 15 feet and generally thin outwardly in all directions. Thicknesses in the northwestern portion of the Highland Rim average 15 feet and thin southeasterly toward the basin. Along the western edge of the basin, the shale thins toward southern Williamson County and the Hohenwald platform (12).

The Maury Formation is commonly 1 to 4 feet thick throughout the area of study and has been identified at every examined outcrop of the Chattanooga Shale (12). In most areas of Tennessee, the Maury is 2 to 4 feet thick, is somewhat thinner in Kentucky, but ranges in thickness from 2 to 6 feet in Alabama.

The massive Fort Payne Chert overlies the Maury Formation in most parts of Tennessee and in the northern portions of Alabama and Georgia. Thicknesses are commonly greater than 100 feet and at some places as much as 275 feet (12). A resistant succession of chert beds 2 inches to 2 feet thick comprise the lower part of the formation (12). Chert grades laterally into the New Providence Shale which covers much of Kentucky and most areas of the Northern and Western Highland Rims.

Uranium Content

Uranium in the Chattanooga Shale has been attributed to the removal of the uranium element from sea water by plant matter on the sea bottom.[4] Richness of the uranium content is thought to be the result of an extremely slow rate of sedimentation (12).

Uranium content within the Chattanooga Shale, both in the entire formation and in individual units, exhibits a fairly uniform lateral distribution over distances of several miles (29). Weighted mean uranium values for the Chattanooga Shale and Maury Formation from localities discussed in this report are the Gassaway Member, 57 ppm, with a standard deviation of 9 ppm; the Dowelltown Member, 23 ppm, with a standard deviation of 9 ppm; and the Maury Formation, 15 ppm, with a standard deviation of 10 ppm. Sample localities are from several States and deviations probably reflect regional trends, some areas being consistently high, others consistently low. Vertical distribution of uranium is distinctly different within the five major stratigraphic units (fig. 4) of the Gassaway and Dowelltown Members, but the relative content of these units remains essentially constant throughout the area (11). The Upper Gassaway consistently contains the greatest amount of uranium. In order of decreasing uranium content are the Lower and Middle Gassaway, followed by the Lower and Upper Dowelltown.

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[4]Reference 28 provides a detailed explanation of the mechanisms of uranium emplacement and amounts attributable to each.

Uranium content of the Gassaway Member is generally considered higher in the Eastern Highland Rim and the greatest number of samples is from this area (figs. 7 and 8). In DeKalb County, Tenn., the central part of the Eastern Highland Rim, the mean uranium content is calculated to be 60 ppm with a standard deviation of 4 ppm. Although less information exists for adjoining Warren County to the south, calculations indicate an identical mean uranium content of 60 ppm with a deviation of 3 ppm. A pattern of fairly high values continues southward into Cannon County. There, the calculated mean uranium value is 59 ppm, but a standard deviation of 6 ppm reflects a somewhat higher variance of values and a possible change in the fairly uniform distribution.

It is possible, judging from existing information that the area of uniform distribution in the Eastern Highland Rim continues eastward under the Cumberland Plateau. Drill cores from Localities 166 and 179 (fig. A-1) indicate the uranium content to be 62 and 63 ppm, respectively. In the Walden Ridge area, the uranium values average about 62 ppm also, but variance from one locality to another is high (51 ppm to 69 ppm between Localities 174 and 175). Drill cores in this area would be expected to give a truer indication of uranium content and average over 65 ppm. Lack of existing data prohibits a reliable estimate of the uranium content, but the area around Locality 168 may contain the best combination of thickness and grade yet encountered (15).

The uranium content within the Gassaway Member tends to decrease, with some irregularity, to the north of DeKalb County. While several localities northeast of the basin exhibit uranium values greater than 60 ppm, county-wide mean values range from 10 to 20 percent below those values calculated for the central Eastern Highland Rim area. The lower grade is characterized by shale with phosphate nodules in the upper unit of the Gassaway. Remaining units of the member, excluding phosphate zones, also have a slightly lower uranium content (12). The uranium content continues to decrease as the shale extends into Kentucky. There, in the northernmost localities from which the greatest Gassaway thicknesses are reported, the shale assays less than 40 ppm uranium.

In the northern and northwestern portions of the Highland Rim, uranium content is comparatively low. From the data available, uranium content appears to decrease in a direction away from the basin. Mean values, by county, average about 53 ppm, somewhat higher than those of the northeastern rim area, but appreciably lower than values from the central Eastern Highland Rim.

In the Southern Highland Rim, uranium values are higher than those in the Eastern Highland Rim but because of its thinness, the Gassaway Member is not considered a minable unit. With the limited data available, generalizations on the uranium distribution further south are difficult. In Blount County, Ala., however, three drill-core localities provide a certain amount of control and indicate the uranium content averages slightly more than 51 ppm.

Because of the lower content and vertical distribution of the uranium, there has been little interest in the Dowelltown Member. The uranium content is generally higher in the Eastern Highland Rim, and in this area the member would probably have its highest economic potential.

FIGURE 7

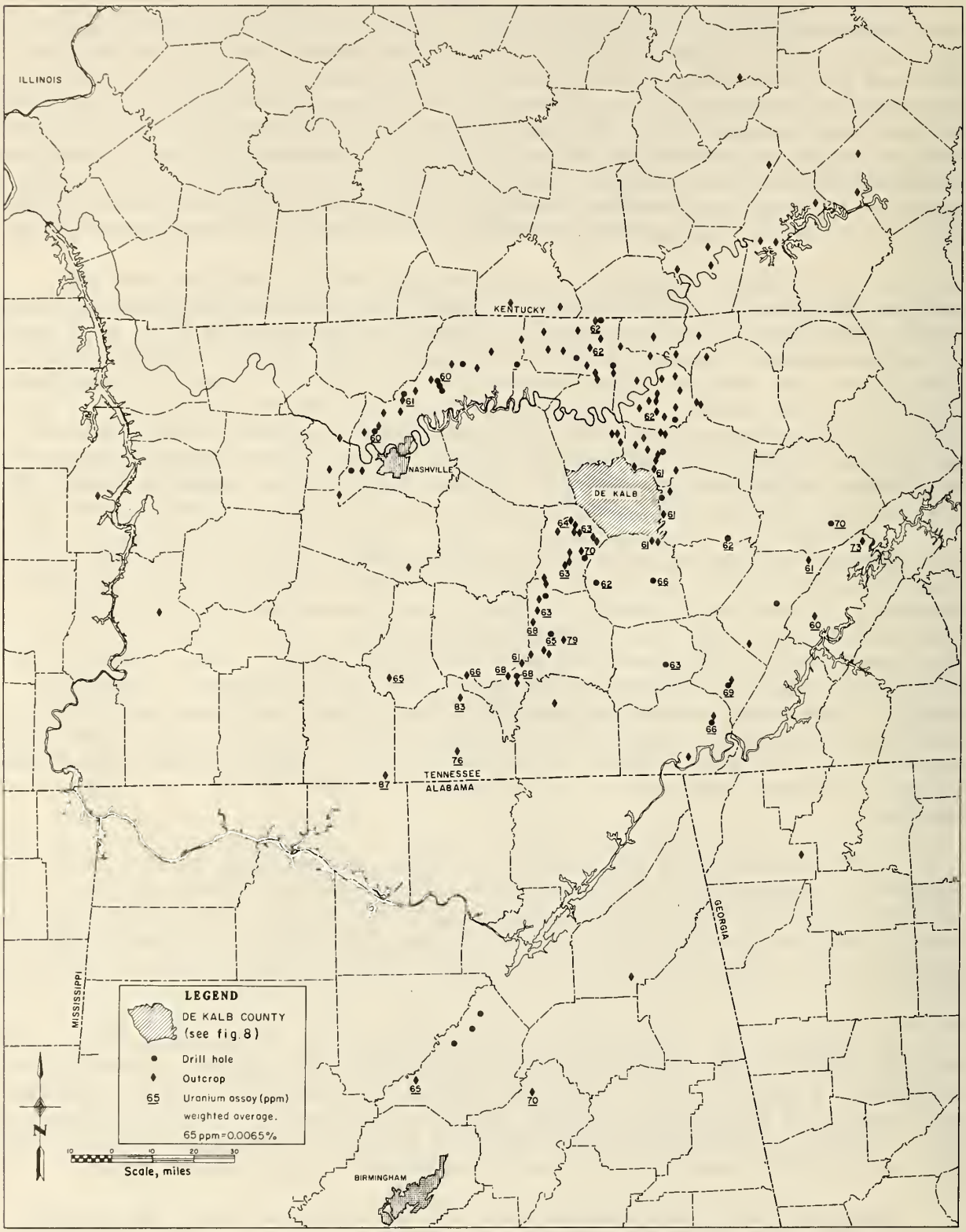

FIGURE 7. - Sample localities where uranium values of the Gassaway Member are greater than 60 ppm (0.0060 percent).

FIGURE 8

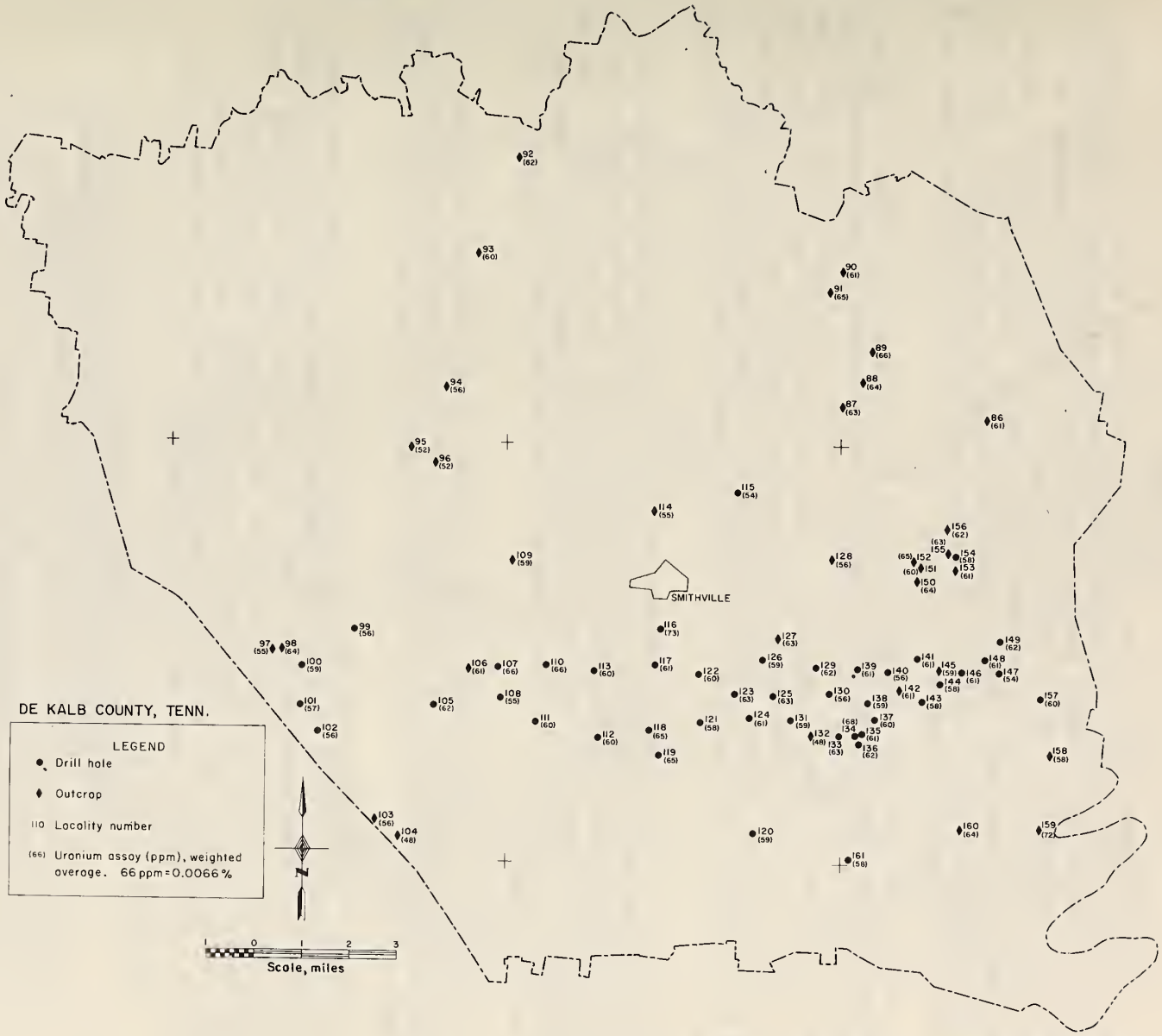

FIGURE 8. - Uranium value of the Gassaway Member at sample localities in DeKalb County, Tenn.

Oil Yield

The Chattanooga Shale is not a source of petroleum as such, but organic material within the shale will, with destructive distillation, yield oil (27). Fisher assays of the Gassaway Member from 34 localities are contained in table A-1, appendix A, and are shown in figure 9. Available data are sparse compared to the amount of information pertaining to uranium content, but the distribution is such that general estimates regarding pyrolitic oil yield can be made. Seven analyses (table A-2, appendix A) of the Dowelltown Member in Tennessee average less than 5 gallons per ton.

One of the areas of highest oil yield for the Gassaway Member is in the central Eastern Highland Rim where mean oil yield values in and around DeKalb County average 8.7 gallons per ton. An oil value of 8.2 gallons per ton from Locality 166 would seem to indicate a fairly uniform distribution from west to east, similar to that exhibited by the uranium content. This uniform pattern is broken, however, because shale in the Walden Ridge area yields between 0.7 and 3.3 gallons of oil per ton. Values also decrease markedly south of DeKalb County.

In the northern Eastern Highland Rim and the Northern Highland Rim, oil yield averages about 8 gallons per ton of shale (6). The northernmost localities in Kentucky are more scattered geographically, but over a large area the shale may yield nearly the same or possibly greater amounts of oil than the approximate 8.7 gallons per ton expected in and around DeKalb County in the Eastern Highland Rim.

Uranium is probably deposited as a result of the presence of organic material (21), and although oil is derived from the organic material, an apparent relationship exists only very locally between the two and not over a widespread area (27).

Three statistical models were specified to see if any significant statistical relationship exists between the observed values for oil versus uranium from the same 34 locations. Table 1 shows that for the models specified, no significant statistical relationship could be determined. The coefficients of determination (R^2) for the equations are extremely low, and the standard errors for the slope are greater than one-half the value of the coefficient, making it no different than zero at the 95-percent confidence interval.

TABLE 1. - Coefficients of regression equations for oil versus uranium with coefficients of determination (R^2) and standard error of regression coefficients

a	b	R^2
LINEAR MODEL [$Y = a + bX$]		
8.87	-34,028.8	0.012
(3.15)	(55,322.8)	-
EXPONENTIAL MODEL [$Y = ae^{bX}$]		
9.52	-8,189.3	0.012
(2.10)	(12,990.9)	-
POWER MODEL [$Y = aX^b$]		
0.959	-0.38866	0.010
(961.17)	(.70089)	-

FIGURE 9

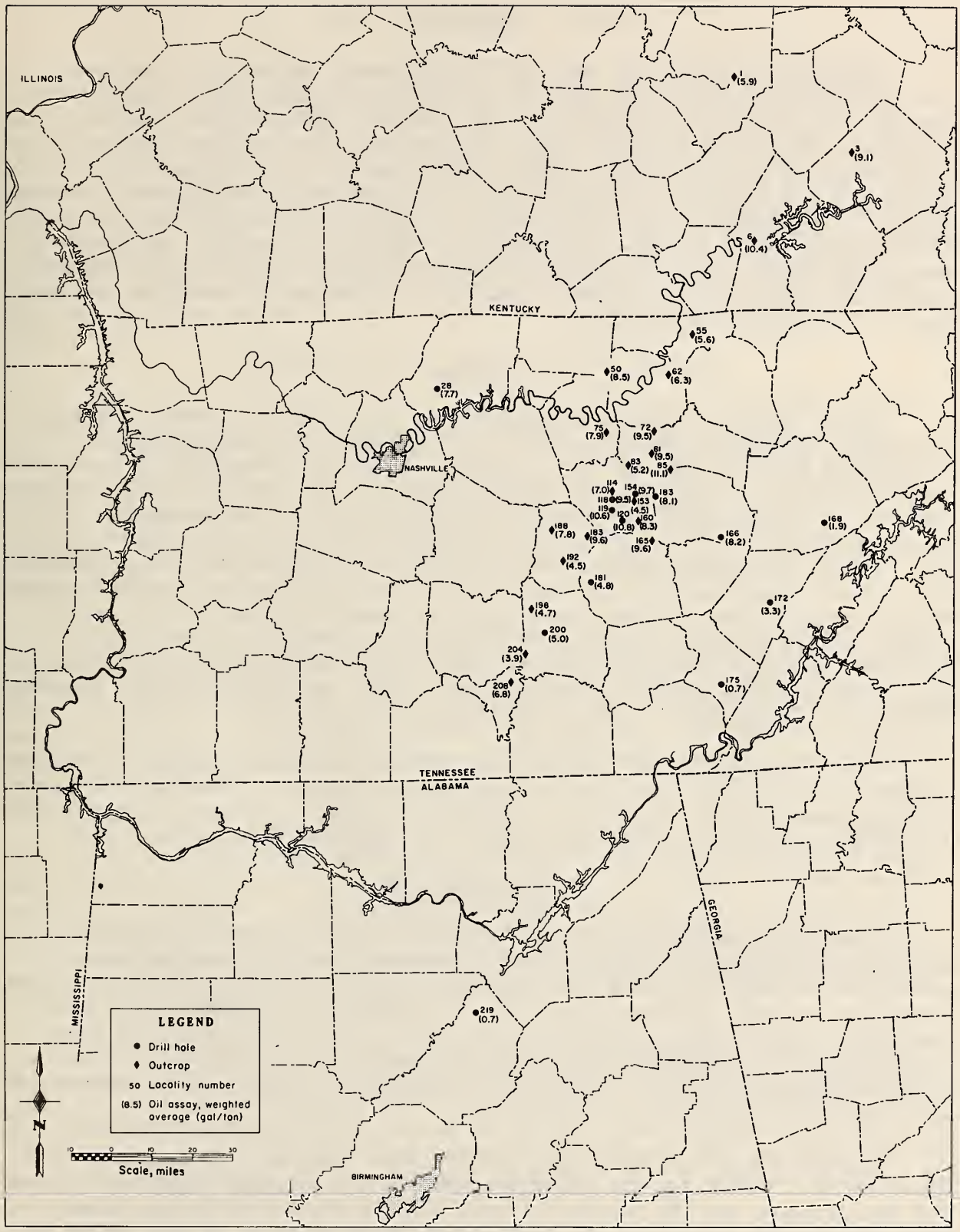

FIGURE 9. - Oil yield values for the Gassaway Member.

Phosphate

Phosphate occurs in the Chattanooga Shale both in zones of scattered nodules within the upper few feet of the Gassaway Member and as sparse disseminated particles, generally in the form of finely divided apatite, throughout the entire formation (6). Phosphorous oxide (P_2O_5), or phosphate, concentrations in the Gassaway Member range from 0.14 to 1.07 percent (table B-2 and figure B-1, appendix B). Concentrations are highest, commonly 0.40 to 0.50 percent, in areas of Walden Ridge and the Eastern and Northern Highland Rims where the zone of phosphatic nodules is present. Analyses of individual nodules from the Gassaway Member indicate a P_2O_5 content which ranges from 20.8 to 28.9 percent. Nodules from the Maury Formation average 29.3 to 33.2 percent P_2O_5 (12).

Pyrite

Pyrite (FeS_2) is generally concentrated in the shale as small, roughly spheroidal aggregates approximately 0.04 mm in size, but larger nodules (4 to 6 mm) are also present (3). Analyses (table B-1, appendix B) indicate concentrations of pyrite in the Gassaway Member (approximately 12 percent) are highest in the Northern Highland Rim. The amount of pyrite gradually decreases southward through the Eastern Highland Rim and into Blount County, Ala., where the Gassaway Member, at Locality 219, contains only 4.49 percent FeS_2. These analyses, however, show only the mean values from random samples and do not represent weighted mean values as generally used in this report. Because pyrite occurs in laminae <0.1 mm or thin layers 1 to 5 mm thick, different sections (generally greater than a foot thick) of the same sample may indicate a wide range of pyrite values. Such circumstances have probably resulted in the several high standard deviations noted.

Most of the sulfur in the shale is present as sulfide combined with iron, forming pyrite or marcasite (1). Weighted mean values of the sulfur content of the Gassaway Member (table B-2, appendix B), which decrease southward, also indicate a tendency for higher values in the Northern Highland Rim.

Trace Elements

Average concentrations of trace elements within the Chattanooga Shale have been determined in approximately 60 randomly selected samples from Localities 30 and 124 (table B-3, appendix B). When compared with the crustal abundance, several elements appear to be enriched in the shale. Data are provided for comparison purposes, and no regional interpretations are made. The analyses are semiquantitative in nature and provide only rough valuations of the elements detected. Certain minor elements may possibly be recoverable on a byproduct basis.

Thorium content has been reported for eight samples (table B-4, appendix B). Values for the Dowelltown Member are slightly higher than those for the Gassaway and the content of each unit is highest in Walden Ridge. Here the thorium content of the Chattanooga Shale is about 12 ppm, which is average crustal abundance of shales (31).

RESOURCE ESTIMATES, URANIUM

Numerous estimates have been made of tonnage and grade of uranium contained in units of the Chattanooga Shale. A Bureau of Mines report (18) described core drilling investigations conducted jointly with the U.S. Geological Survey and estimated measured and inferred reserves of uranium, based on drill core analyses, for the Gassaway Member within area blocks (fig. 4). U.S. Geological Survey reports have estimated uranium resources for units and members of the Chattanooga Shale by county and geologic province (6), metallic uranium content (12), and reserves for the Gassaway Member in 21 square miles of the Youngs Bend area, DeKalb County, Tenn. (20). Personnel with the University of Tennessee have also estimated uranium reserves within certain Tennessee counties based on their contract work with the AEC (26).

Methodology for Resource Calculations

From a mining standpoint, the Gassaway Member appears the more economically attractive unit in the Chattanooga Shale. The combination of its widespread distribution, uniform thickness, and the higher uranium content with its relatively vertical consistency makes the Gassaway a logical choice to be mined; resource estimates determined for this report are for the Gassaway Member only. Uranium potential of the Dowelltown Member is questionable because of the 5- to 10-foot-thick, nearly barren claystone unit overlying the lower black shale.

Geologic maps published by the State of Tennessee, Division of Geology, were enlarged and planimetered to determine the areal extent of the Gassaway Member in selected counties. Data from the files of the University of Tennessee (graphic logs of measured sections of the Gassaway Member (32)) were used in addition to thicknesses presented in table A-1, appendix A, in calculating the mean and standard deviations of thickness for the Gassaway Member in the 12 counties.

Data from both outcrops and drill holes were used in resource determinations since no significant difference could be found between the means and the standard deviations for each in DeKalb County, which has the largest data base of all counties. The mean value for outcrops and drill holes was 60.3 versus 59.9 ppm, respectively, while the standard deviations were 5.2 versus 3.7 ppm, respectively. The 0.4 ppm difference in the means and the 1.5 ppm difference in standard deviations is well within the ±5 ppm precision limits of analysis of individual samples.

When the thickness of the Gassaway Member was assessed, a range rather than a one number estimate best served the purpose of arriving at a realistic appraisal of uranium resources for the counties. To obtain a range of values, two thicknesses were determined using one-half of one standard deviation above and below the mean thickness. For example, in Coffee County the mean Gassaway thickness is 13.23 feet with a standard deviation of 2.20 feet (table 2). The calculated mean thickness ranges from 12.13 to 14.33 feet.

TABLE 2. - Uranium resource estimates of Gassaway Member in selected Tennessee counties

County	Area (square miles)		Thickness				Uranium content			Resources[2]			
	Total	Underlain by member	Number of observations	Mean ($\bar{x}$), feet	Standard deviation(s), feet	Bias[1]	Number of observations	Mean ($\bar{x}$), ppm	Standard deviation(s), ppm	Shale (million short tons)		Uranium (thousand short tons)	
										Low	High	Low	High
Cannon..	271	127	29	12.74	1.48	None..	14	59	6	3,049	3,430	180	202
Clay....	232	180	31	16.82	2.75	..do..	4	52	6	5,564	6,554	289	341
Coffee..	434	381	37	13.23	2.20	..do..	9	63	9	9,223	10,900	581	687
Davidson	508	110	12	10.81	3.04	High..	10	55	6	2,379	3,048	131	168
DeKalb..	278	169	109	14.91	2.16	None..	78	60	4	4,666	5,376	280	323
Jackson.	323	130	85	15.95	2.18	..do..	13	48	7	3,865	4,432	186	213
Macon...	304	232	54	15.08	1.76	..do..	13	52	7	6,591	7,407	343	385
Putnam..	404	360	18	17.10	3.60	..do..	11	53	7	11,019	13,613	584	721
Smith...	323	25	7	13.78	2.05	..do..	4	49	4	638	740	31	36
Sumner..	534	258	23	11.27	2.62	High..	11	53	4	5,832	7,174	309	380
Warren[3].	439	439	9	14.85	2.30	..do..	6	60	3	12,998	15,018	780	901
White...	382	382	8	15.50	4.30	None..	5	54	11	10,240	13,450	553	726
Total	4,432	2,793	-	-	-	-	-	-	-	76,064	91,142	4,247	5,083

[1]See text for explanation of bias.
[2]Assuming a specific gravity of 2.3 for the Gassaway Member.
[3]Additional data from adjoining counties supplement three assay values within Warren County.

If isopach maps (12, 26) and/or point distributions indicated an overall thickness greater than the calculated mean, a bias was introduced. A bias indicates the member thickness ranged from the mean to one standard deviation above the mean. For example, in Sumner County the mean thickness of the Gassaway is 11.27 feet with a standard deviation of 2.62 feet, but the calculated mean thickness of the member is assumed to range from 11.27 to 13.89 feet.

Weighted mean uranium values for each locality presented in table A-1, appendix A, were used in calculating the mean ($\bar{x}$) and standard deviation(s) of uranium content for the counties. A range of uranium values was not introduced in the resource calculations as the standard deviations closely approximate individual analysis accuracy.

Resources, Gassaway Member

The Chattanooga Shale of eastern Tennessee is considered a submarginal uranium resource (13). Uranium content of the shale is too low to be considered an ore, and analytical data are too limited for precise resource determinations except for a confined area in DeKalb County, Tenn. However, with extrapolation, based on assumptions that uranium content and unit thicknesses are generally uniform over large areas, an order of magnitude of the amount of uranium contained in the Gassaway Member has been determined for a 12-county area. The estimated resources prepared during the course of this study should be considered as indicated.

Counties (fig. 10) for which resource estimates were prepared were selected solely on the basis of the quantity and distribution of assay and thickness data. Within the 12 selected counties (table 2), uranium resources within the Gassaway Member range from 4.2 to 5.1 million short tons contained in 76 to 91 billion short tons of shale. These figures represent in-ground tonnages and do not allow for mining or processing losses.

Resources Versus Projected Cumulative Demand

For comparative purposes, the magnitude of uranium resources contained in the Gassaway Member of the Chattanooga Shale are related to the projected cumulative United States and world demand for U_3O_8 from 1975 to 2000 (fig. 11).[5] Depending on the magnitude of mining and the efficiency of the mining and processing recovery of the shale, a substantial portion of the cumulative United States and world demand could be satisfied. With a 50-percent mining and 70-percent processing recovery, approximately 1.48 short tons of the 4.2 million short tons of uranium could be recovered. This would be greater than 75 percent of the cumulative United States demand requirements for U_3O_8 through the year 2000 (33).

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[5]U.S. case D, foreign case L, 0.30 percent tails assay, etc., explained fully in reference 33.

FIGURE 10

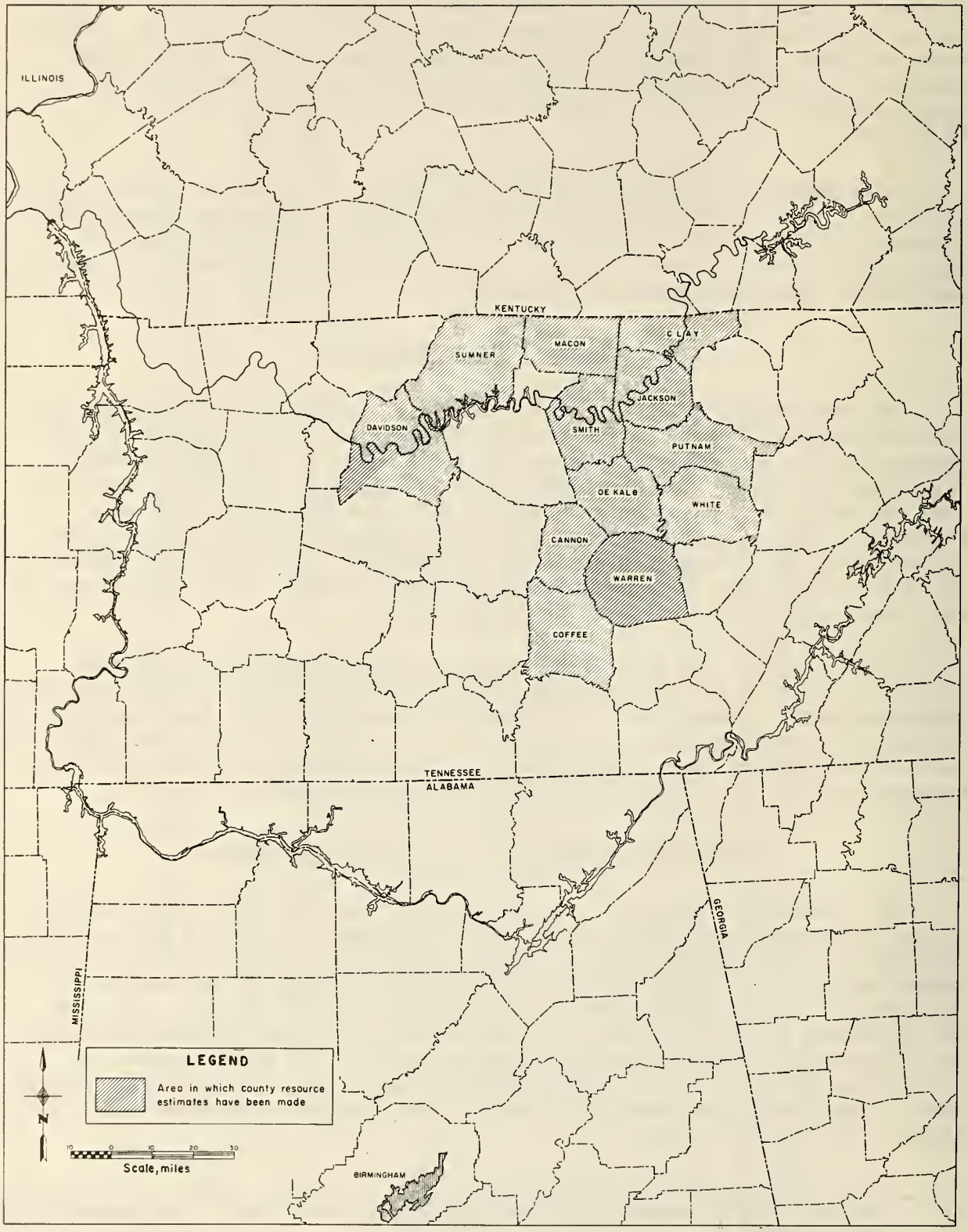

FIGURE 10. - Counties for which uranium resource estimates of the Gassaway Member have been determined.

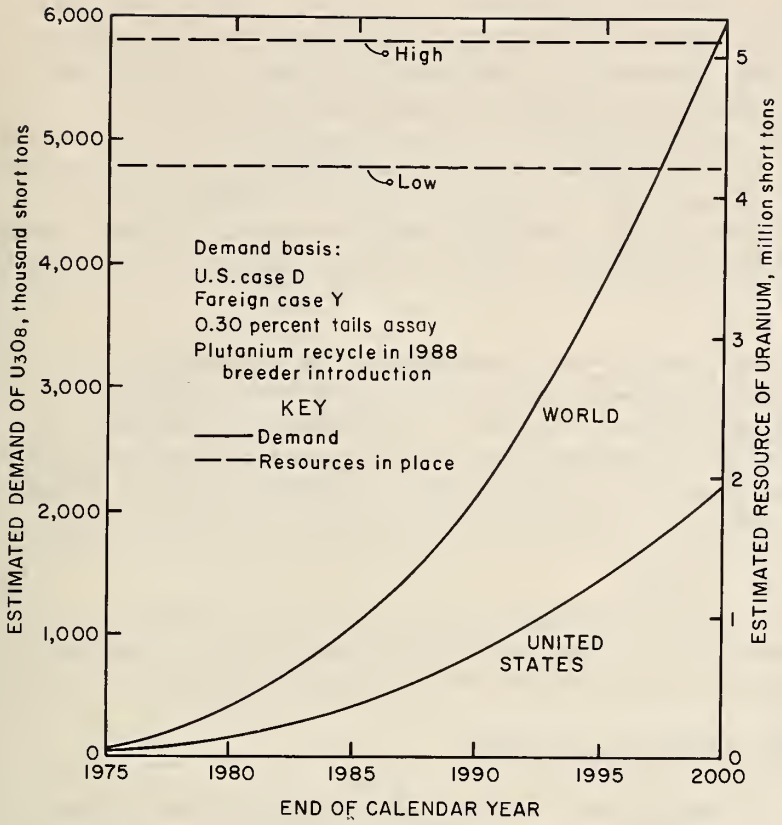

FIGURE 11. - Comparison of resources in 12 selected Tennessee counties versus projected cumulative United States and world demand.

CONSIDERATIONS IN MINING

Mining costs have not been developed during this study because future utilization would depend on advances in mining and metallurgical technology. Therefore, costs developed for such a situation would be purely hypothetical. Some inferences related to costs, however, can be drawn from the present "state of the art."

Previous investigations of the Chattanooga Shale were concerned primarily with this shale being a source of uranium. Large deposits of richer grade had not been discovered, and the value of uranium was tied to Government demand. Consequently, tonnage, grade, and mining costs were the most important factors influencing mine site selections.

Major factors to consider in mining the Gassaway Member are composition, location, and attitude of the shale, and stratigraphic units lying above and below the shale. With respect to mining only for uranium, a general requirement is the need for an enormous tonnage of shale. If other products were recovered along with uranium, this tonnage requirement might not be as economically burdensome.

Other constituents of the shale undoubtedly would affect the selection of a mine site, depending on the feasibility of recovery. These would include oil, pyrite, phosphate, and possibly some trace elements. Silica content of the shale could also influence mining and processing procedures.

Within the study area, there are only 34 sample localities, given the analytical data base, for which a weighted mean oil yield could be determined for the entire Gassaway Member (table A-1, appendix A). Additional assay data based on core drilling would have to be developed to provide precise oil yield information before adequate selection of a mining area could be made.

From the limited data presented in tables B-1 and B-2, appendix B, there is a slight indication that pyrite and sulfur content within the Gassaway is

highest in the Northern Highland Rim of Tennessee. If this is the case, and if pyrite were converted to sulfuric acid for use in leaching uranium, investigations for a mine site could be directed to pyrite-rich areas. Pyrite contained in the shale can be decomposed by aqueous oxidation and the acid produced can be used to extract uranium (24). Further research will be needed to test whether this reaction is applicable to in situ leaching of uranium, by itself, or with a combination of methods. If pyrite were not considered a recoverable product, but a detriment, the reverse would be true. In any event, mining operations may have to consider the effects of acid water formed from oxidation of the pyrite.

If phosphate in the Gassaway Member were considered an economically recoverable byproduct, consideration would have to be given to selection of a mine site in an area of high-phosphate content. Presumably, the Maury Formation would be removed during underground mining to leave a more stable roof of Fort Payne Chert. The lower 1 to 3 feet of the Maury has been mined for its phosphate content in the past and this zone would be a major source of phosphate.

No substantive conclusions can be reached on the possible effects of trace elements in mine site selection. The analytical data base is limited and is in need of expansion before any conclusions are to be reached.

Past Mining Experience

The Sligo adit is the only underground mining experience of record for the Chattanooga Shale. From 1948 to 1949, this experimental adit was driven for the U.S. Geological Survey by the Construction and Maintenance Division of the Tennessee Valley Authority. The purpose of the adit was to obtain 12- to 15-ton samples of fresh shale for large-scale laboratory tests as well as to gain insight on mining conditions (4).

In April 1953, the Bureau of Mines entered into contract with the AEC to obtain engineering data relative to the utilization of the Chattanooga Shale. As part of this investigation, an experimental mine site was proposed, with provisions for expansion to a permanent production operation. The mine site selection was based on geological investigations conducted by the U.S. Geological Survey and exploratory and development core drilling performed under the direction of the Bureau. Appraisal of information available at the completion of drilling indicated that the Youngs Bend area of DeKalb County, Tenn., had the best potential for future large-scale production of uranium (14).

The general location of the mining area in DeKalb County, Tenn., is shown in figure 12. The proposed experimental mine area and production mine and mill site are identified in figure 13. This figure has been adapted from previously published literature (18) which summarized the selection of the Bureau mining area. The original field numbers of the drill holes have been retained in the illustration, and the locality cross-reference listing (table A-3, appendix A) identifies the numbers assigned to these drill holes in this report. Two holes, PC-4 and PC-5, drilled for mining data at the Pine Creek experimental mine site depicted in figure 13, do not appear in the compilation

FIGURE 12

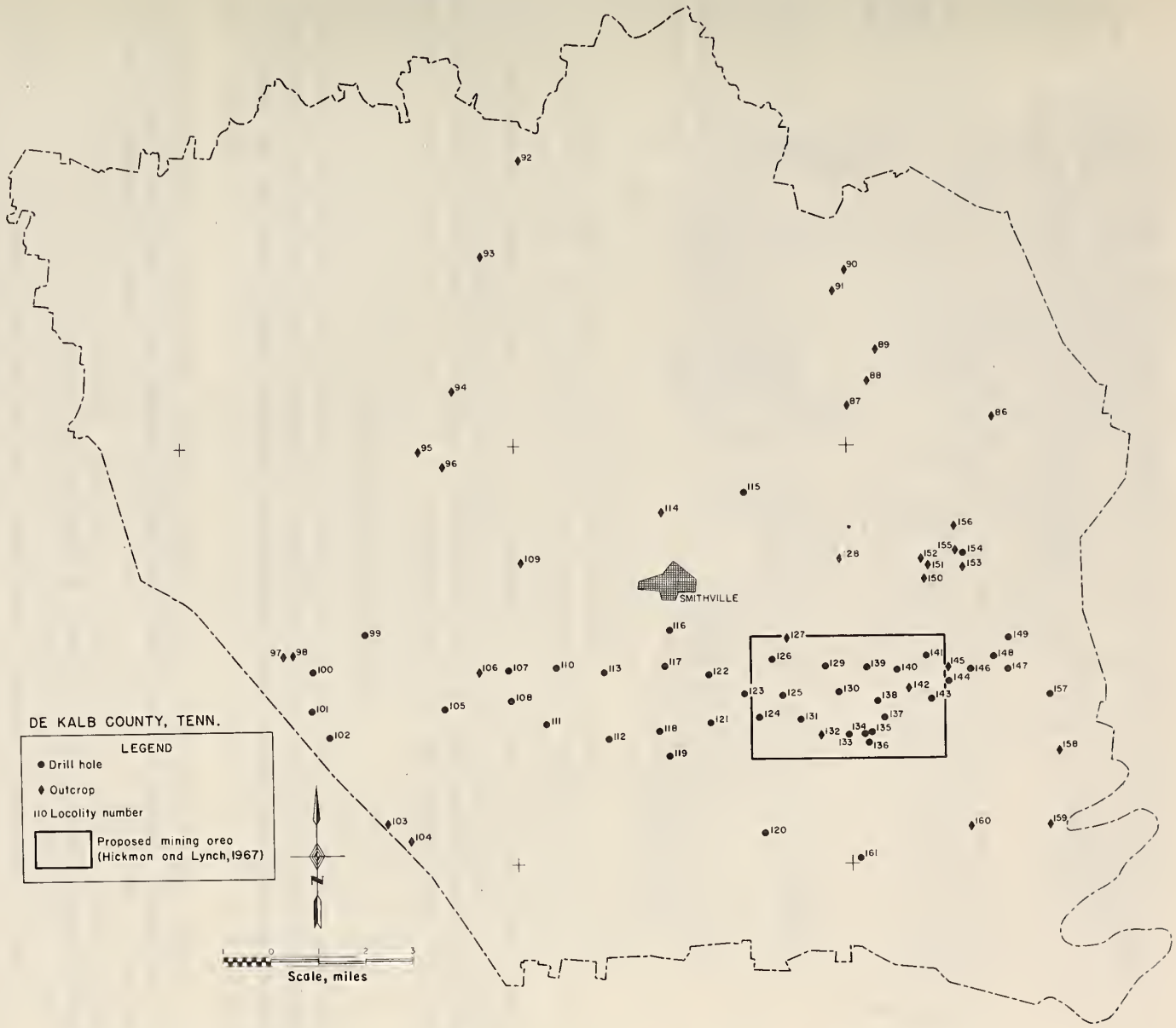

FIGURE 12. - General location of previously proposed mining area, DeKalb County, Tenn.

FIGURE 13

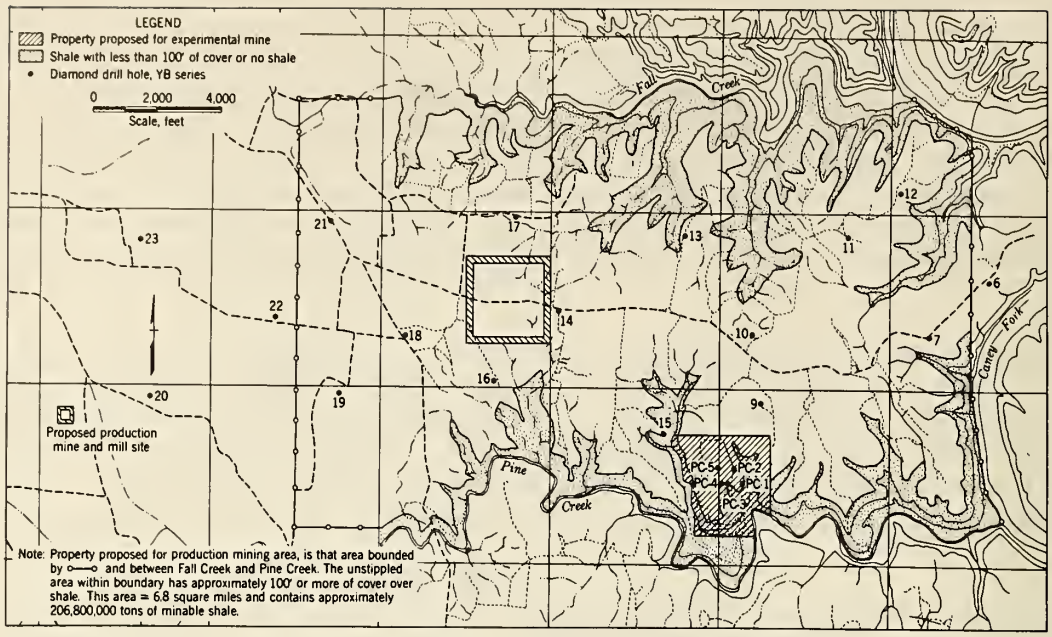

FIGURE 13. - Location of proposed mine area and mill sites, DeKalb County, Tenn. (From Hickman and Lynch (18).)

of data presented in table A-1, appendix A. There is no record of uranium analyses of these drill cores, and the data base of this report has been limited to only those localities for which a weighted average uranium value could be computed for the Gassaway Member.

Underground Operations

Early investigators considered an underground operation the most feasible method of mining. In the Eastern Highland Rim area, the area with the highest uranium content, the shale lies progressively under more cover to the east, reaching a depth of 360 feet at drill hole Locality 166 (fig. A-1, appendix A).

In the vicinity of the proposed experimental mine area, the Chattanooga Shale and Maury Formation are overlain by the competent Fort Payne Chert. In a report on the Sligo adit (4), it was stated that the Fort Payne Chert, in general, makes a good roof, though at outcrops numerous strong joints are observed which could continue long distances underground.

Directly beneath the Fort Payne Chert is the Maury Formation, a less competent, dominantly shale unit. Preliminary plans for an experimental underground mine developed by the Bureau of Mines assumed that the Maury would not be self-supporting and would have to be removed (14). As a consequence, dilution of the uranium grade in the Gassaway Member would have to be considered, unless selective underground mining methods are developed which would allow for the separation of material mined from the units.

Another factor to be considered in an underground operation, unique to uranium mining in black shale, is fire hazard. The shale is combustible and tests performed by the Explosives Branch of the Bureau of Mines indicate dust clouds of the shale are ignitable and explosions might result if normal precautions are not followed (4).

Ground subsidence would have to be considered in large-scale underground operations. Effects could be reduced with careful mine planning. Adequate ventilation systems would have to be considered in underground operations to prevent possible buildup of radon daughter concentrations from emanations of radioactive materials within the shale.

Pertinent properties of the Gassaway Member are listed below for the reader wishing to make further study of underground mining considerations: Apparent specific gravity is 2.30; apparent porosity ranges from 1.6 to 1.7 percent; tensile strength ranges from 110 to 130 pounds per square inch; compressive strength ranges from 16,000 to 16,300 and modulus of rupture ranges from 330 to 370 pounds per square inch (2).

Stripping Operations

Reconnaissance investigations for areas in which the Chattanooga Shale or its correlatives could be mined by stripping were carried on by the U.S. Geological Survey between August 1948 and April 1949 (25). Of the areas investigated, only those in Kentucky had enough shale tonnage available to be considered for uranium extraction. However, the low-uranium content reported negated these areas for selection as a mine site. In addition to grade, the extent and thickness of the "tough" Fort Payne Chert is of primary concern with regard to the feasibility of stripping operations. Areas in northern Tennessee and Kentucky, where the correlative of the Fort Payne (the New Providence Shale) overlies the Maury Formation and Chattanooga Shale, are the most likely candidates for stripping operations. Where the thicknesses permit, stripping of the less competent New Providence Shale would be more economically feasible.

With respect to uranium, dilution from the Maury Formation and from phosphatic zones within the Gassaway Member could be controlled through selective stripping operations.

If multiple products could be recovered from the shale, based on breakthroughs in extractive metallurgy and an enlarged analytical data base, there would be a need for a reassessment of strip mine areas and the economics involved.

In Situ Operations

Environmental factors require consideration of in situ recovery of products from the Chattanooga Shale. The large tonnage of raw shale needed to support a conventional operation would require disposal of huge quantities of spent shale and possibly create acid-water and ground-subsidence problems with inherent environmental degradation. The technical and economic

feasibility of in situ operations will have to be determined through experimentation. To date, substantive methodology has not been developed for this type of recovery operation.

Investigations into the feasibility of in situ production of oil from the richer oil shales of the Western States are being conducted by the Bureau of Mines. Methods of fragmenting oil shale formations, preparatory to in situ retorting, have been developed along with procedures to determine extent of fragmentation (22). Field experiments have been conducted on in situ retorting of the western shales (7). Results of these studies could be applicable to the Chattanooga Shale as follows:

1. Combustion zones can be established in fractured oil shale deposits.

2. Combustion zones can be maintained and moved through the fractured shale by injection of air.

3. Free oil can be recovered.

One of the problems of in situ recovery (retorting) for oil is maintaining sufficient permeability in the oil shale to allow the process to be applied. Changes in the permeability and compaction of broken western oil shale during retorting have been investigated by the Bureau of Mines in laboratory studies. Grade of western oil shales studied ranged from 20.6 to 46.7 gallons of oil per ton. Under test conditions, the leaner oil shales experienced only minor apparent permeability reductions, but the richer shales lost essentially all permeability (8).

The minor apparent permeability loss of leaner shales during in situ retorting may be an important factor if uranium were to be recovered after retorting. However, it has been reported in work conducted by the Mineral Beneficiation Laboratory, Columbia University, that in their tests of batch leaching, retorting markedly reduced subsequent uranium extraction (24). Research will be needed to determine the order of extraction of possible recoverable products from the shale.

PROCESSING OF SHALE

To date, no commercial or pilot plant operation has been undertaken to process the Chattanooga Shale for recovering uranium or oil. This is because of the very low concentrations of either product compared with concentrations in existing western deposits which are economically more attractive. However, laboratory work has been and is currently being conducted which evaluates several of the more promising processes for the recovery of uranium.

The most notable work for the recovery of uranium to date was done in 1960 by Columbia University for the AEC (9). This research work was undertaken to find methods of beneficiating the Chattanooga Shale for its uranium content and to make a preliminary techno-economic evaluation of the process.

The two most promising processes are (1) countercurrent leaching of raw shale with sulfuric acid and (2) oxygen pressure leaching in which acid production and leaching were simultaneously achieved (9). Both processes recovered between 70 to 80 percent of the uranium from the shale, depending primarily upon the amount of reagent and the number of steps. A third method was discussed--high temperature chlorination of shale--but time and budget considerations did not permit complete evaluation.

Research on percolation leaching--a comparatively simple, single-step technique resulting in approximately 34 percent uranium recovery on minus 3-mesh ore--is currently being conducted by the Bureau of Mines in the Salt Lake City Metallurgy Research Center.

The major difficulty in processing the shale for uranium is economic. With the more elaborate multistage processes, a high yield can be obtained but at a very high cost. The less costly, more economical single-stage processes suffer from comparatively low recovery rates.

The following two solutions, which chould possibly change the economics of the situation, exist: Advances in technology which would allow higher recovery rates at lower costs and/or byproduct recovery of other commodities from the shale, that is, oil, phosphate, and sulfuric acid which could partially justify some of the initial process expense. No substantive work has been done on the joint recovery of uranium and oil (the most promising byproduct) from the shale to date. The Gassaway Member contains less than 10 gallons of oil per ton of shale compared with 20 to 40 gallons for western shales. These lower concentrations in the Gassaway almost dictate that if the oil from the Gassaway were to be recovered economically, it must be done as a byproduct or coproduct. Another problem complicating the matter, however, is that oil retorted from the Chattanooga Shale has a high-sulfur content and is very corrosive (35). Further work must be done in order to adequately assess any process technique for future consideration.

ASSESSMENT OF SELECTED LAND DISTURBANCE PARAMETERS OF MINING CHATTANOOGA SHALE

A model has been developed to determine land disturbance measured by the total tons or acres of shale to be mined and reclaimed and the number and areal magnitude of each mining operation if the Gassaway Member of the Chattanooga Shale is to satisfy 1 percent of the domestic demand for uranium in the United States in 1991. This year was chosen because (1) it is in the decade of the nineties when the uranium supply is forecasted by AEC to be short and (2) it is far enough in the future (15 years) that the Gassaway Member may be utilized as a potential source of supply for uranium. One percent is used because projected estimates in the model can be easily factored to greater demand percentages.

For this model, only large underground operations are considered. However, in some instances, strip mining may be possible where favorable geologic and environmental conditions exist.

Methodology for Estimating Land Disturbance Parameters

Projected estimates of tonnages or acres of the model are determined by using the following four variables: (1) Average thickness of deposit; (2) uranium content of the shale; (3) mining recovery; and (4) processing recovery of uranium.

The range of values for these four mining parameters was determined by (1) examining and analyzing geologic data presented in other reports and (2) conferring with qualified experts in the field.

The values in the model for average thickness of deposit--8, 11, 14, 17, and 20 feet--were determined by calculating the mean and standard deviation for thicknesses within the study area. For the uranium content, values range from 0.0045 to 0.0065 percent and are determined by the same method as that used for thickness of deposit. Values for mining recovery, 65 to 85 percent, are speculative and based on recovery rates for underground shale mining operations that currently exist in other geographic areas.

Selected processing recovery rates range from a low of 40 to a high of 70 percent. Forty percent recovery is now being achieved in laboratory tests conducted by the Bureau of Mines on the Chattanooga Shale (see section on Processing of Shale). With advances in technology, a higher processing recovery may be economically attainable. Although 70-percent recovery has been obtained in laboratory tests, it is well above any known recovery rate based on economics to date and is only presented here to show possible scenarios in the model.

Besides the ranges of the four mining parameters, the remaining assumptions in the model are as follows:

1. One percent of the estimated demand for U_3O_8 with a 30-percent tails assay in 1991 will be approximately 2.1 million pounds (about 1.8 million pounds uranium (33)). The medium forecasted demand by the AEC for U_3O_8 in 1991 was chosen, so an average amount of environmental disturbance may be estimated (in terms of tons and acres) when trying to satisfy 1 percent of the demand for uranium from the Gassaway Member.

2. The average density of the Gassaway Member is assumed to be 143.52 pounds per cubic foot, based on a specific gravity of 2.30 (2).

3. The projected size of a mining operation is 6,250,000 tons per year (or 25,000 tons per day for a 250-day year). Although most current underground operations are not this large, operations this size could become economically and technically feasible. Large individual mining operations would also be consistent with the relatively large tonnages of shale required to produce significant quantities of uranium.

Terms for the model which derive the values for the combinations in the equations are as follows:

A = Thickness of Gassaway Member (feet)

B = Uranium processing recovery (percent)

R = Mining recovery (percent)

L = Uranium content of shale (percent)

M = Uranium recoverable per acre (pounds)

T = Tons of recoverable shale per acre

W = Recoverable uranium per ton of shale (pounds)

Z = Acres of shale to be mined (per year)

I = Tons of shale to be mined (per year)

H = Number of mining operations required

P = Acres to be mined per year (per operation)

Model

1. Tons of recoverable shale per acre

$$(T) = \frac{A \cdot 43{,}560 \text{ (square feet per acre)} \cdot 143.52 \text{ (pounds per cubic foot)}}{2{,}000 \text{ (pounds per ton)}} \cdot R$$

2. Pounds of recoverable uranium per ton of shale

$$(W) = L \cdot 2{,}000 \cdot B$$

3. Pounds of uranium recoverable per acre

$$(M) = W \cdot T$$

4. Acres of shale to be mined per year

$$(Z) = \frac{1{,}800{,}000 \text{ (pounds per demand)}}{M}$$

5. Tons of shale to be mined per year

$$(I) = \frac{1{,}800{,}000 \text{ (pounds per demand)}}{W}$$

6. Number of mining operations required

$$(H) = \frac{I}{6{,}250{,}000 \text{ tons}}$$

7. Acres to be mined per year per mining operation

$$(P) = \frac{6{,}250{,}000 \text{ tons}}{T}$$

Analysis and Results of Model

Two items which hold significant interest in this model when trying to estimate land disturbance are linear acres and tons of the Gassaway Member to be mined per year to satisfy 1 percent of the domestic demand for uranium in 1991. Even though the acres to be mined are underground, they are considered a part of the environmental impact to take place because they reflect the areal magnitude of the mining operations.

The total tons of shale to be mined per year (given a projected set demand for uranium) is a function of the following two variables: (1) Uranium content of the shale and (2) processing recovery of uranium from the shale (see appendix C). The largest tonnage to be mined per year is approximately 50 million tons when the uranium content is 0.0045 percent and the processing recovery is only 40 percent. Eight mining operations would be needed to extract this tonnage.

The condition under which the fewest tons of shale (approximately 19.7 million) need to be mined is when the uranium content is 0.0065 percent and the processing recovery is 70 percent. Admittedly, 0.0065 percent is somewhat high in most areas for average uranium content and a processing recovery of 70 percent is economically beyond current technology for such low concentrations. However, the combination is presented to show the effect of such a polar consideration. Consequently, the number of mining operations needed in this example falls to a low of approximately 3.2.

Two additional variables--(1) mining recovery and (2) member thickness, along with processing recovery and uranium content--affect the total linear acres to be mined. As shown in the model, the acres to be mined per year range from a low of 372 to a high of 3,076. The values for the parameters for the low acreage are a member thickness of 20 feet, a uranium content of 0.0065 percent, a mining recovery of 85 percent, and a processing recovery of 70 percent. Again, the high and low estimates are a result of accruing the combinations of all high and all low values for each parameter, which is unlikely. These polar estimates give a scenario for range only. In reality, a feasible estimate of linear acres and tons lies somewhere between these estimates.

Local Land Disturbance Impact

Another method of measuring the local land disturbance impact of utilizing the Chattanooga Shale (Gassaway Member) as a source of supply for uranium

is by comparing the magnitude of activity of such an operation with the scope of similar operations in the same área.

In 1972, approximately 67 million tons of material was mined in recovering the seven leading mineral commodities produced in the State. Under the most ideal conditions in the model, 20 million tons of shale representing 30 percent more mining activity in Tennessee would result if uranium were mined from the Gassaway Member.

The total land disturbed in mining coal, clay, sand and gravel, phosphate rock and barite, all surface operations, was 3,231 acres in 1973 (30).[6] The model shows a range of 372 to 3,076 linear acres disturbed below ground. However, in a linear comparison, the areal extent of the mining operation ranges from 11.1 to 95 percent of the total surface operations now occurring in the State. If the Gassaway Member, under the most ideal mining and processing conditions, were to supply 10 percent of the total domestic demand for uranium in 1991 then (1) the total tons of material mined would be approximately 300 percent larger than the tonnages mined in 1972 and (2) total acres mined would be greater than the total areal extent of these same mining operations shown in table 3.

TABLE 3. - Selected mineral commodities mined in the State of Tennessee, 1972[1]

	Quantity (thousand short tons)
Clays[2]	1,718
Coal (bituminous)	11,260
Copper (estimated total tons of ore)	1,616
Phosphate rock	2,154
Sand and gravel	10,839
Stone	35,942
Zinc (estimated total tons of ore)	3,391
Total	66,920

[1]Adapted from Babiteke, H. R., W. D. Hardeman, and R. E. Hershey. The Mineral Industry of Tennessee. BuMines Minerals Yearbook 1972, v. 2, 1974, pp. 661-677.

[2]Excludes Fuller's earth.

In terms of potential population exposure, Tennessee had approximately 100 people per square mile in 1973 (34). For comparison, in the mountain States of Montana, Wyoming, Colorado, and New Mexico, from which significant amounts of future coal, uranium, and oil shale are projected to be mined, the population per square mile ranges from 4 to 23. However, since the exact location of future mining operations for oil shale, coal, or uranium is not known, no precise conclusions can be reached at this time.

[6]No data were available for land area disturbed underground.

Comparative Land Disturbance Impact

On a comparative basis, energy balance and total environmental change take some degree of precedence in policy considerations. Preliminary estimates by Holdren (19) of comparative land damage of utilizing a selected area of strippable Chattanooga Shale versus surface-mined eastern coal indicate that for approximately equivalent energy outputs, 3 times as much overburden must be removed and 19 times as much land area must be excavated in the coal mining operation as in the shale mining operation. Therefore, for specific areas on a preliminary energy-balance basis, shale does not fare badly. However, caution must be taken when using these figures because no shale has been mined yet to permit reliable estimates of environmental impact and most future shale mining operations are projected to be by underground rather than strip mining operations.

RECOMMENDATIONS

This report perused some of the mining and land disturbance issues raised by examining the Chattanooga Shale as a future source of supply for uranium. Large resources of uranium do exist in the Gassaway Member, and technically, can be obtained in some degree by current mining and processing methods. With advances in technology, progress may be made in the economic recovery of uranium from the Gassaway Member. However, major inquiries about the comparative cost to society of utilizing the Gassaway Member as a source of future energy supply are essential.

Major areas for further study are as follows:

1. An investigation into the net change in energy balance that will occur if and when lower grade ores (60 ppm rather than 2,000 ppm uranium) are used as a source of nuclear fuel. Currently, steady-state Light Water Reactors (LWR) have an energy input-output ratio of approximately 1 to 15 when using uranium derived from high-grade deposits. If the Gassaway were utilized (60 ppm uranium) in the absence of more economical uranium deposits, this ratio would change. A preliminary study is needed to determine the increased amount of energy input needed to mine, mill, and process the Chattanooga Shale versus higher grade deposits and analyze how this would affect the energy ratio of LWR's.

2. Amplification of the existing analytical data base (analyses for uranium and oil or other possible byproducts).

   a. Core obtained by previous drill investigations (splits are in storage at the Bureau's core library) should be reanalyzed for constituents other than uranium and oil.

   b. Cooperative agreements with industry should be initiated to analyze sections of the shale penetrated during industry's exploratory core drilling for other commodities (such as lead or zinc).

   c. Further evaluation of the vast areas for which no analytical data currently exist would require additional drilling and core analyses.

3. Evaluation of processing techniques applicable to low-grade deposits such as the Chattanooga Shale and designed to include in situ recovery.

4. Method and rate of utilization of lower grade energy supply sources. For example, should low-grade uranium resources be used as a supplement and/or replacement for conventional energy sources (coal, oil, gas) and what impact would such rates of implementation have environmentally on the land areas disturbed?

5. Examining the socioeconomic ramifications of using an area such as Tennessee as a major supplier of energy replacing the national role played by fossil fuels.

Further work on the Chattanooga Shale should concentrate on developing more geologic data on the formation, estimating net energy balances, and determining the sociological and environmental impact that will occur if the shale is to be mined and processed for its uranium.

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APPENDIX A.--URANIUM AND OIL ANALYSES

TABLE A-1. - Sample data, uranium content, and oil yield of the Gassaway Member, Chattanooga Shale

Locality No.		Location			Sample type		Thickness, feet	Assay[3]		Assay reference[4]	
This report	Field[1]	County, State	Quadrangle (7-1/2 minute)	UTM[2] coordinate, zone 16	Out-crop	Drill hole		Uranium, percent	Oil, gal/ton	Uranium	Oil
1	18N-12	Marion, Ky.....	Bradfordsville.....	41467-6587	X		30.00	0.0039	5.9	6	6
2	17P-8	Adair, Ky.....	Dunnville.....	41116-6691	X		25.50	.0035	---	11	--
3	17R-6	Pulaski, Ky.....	Science Hill.....	41154-7036	X		38.75	.0038	9.1	6	6
4	17R-9	.....do.....	Delmer.....	39998-7035	X		37.20	.0037	---	11	--
5	17Q-4	Russell, Ky.....	Eli.....	40976-6851	X		28.00	.0047	---	11	--
6	16P-1	.....do.....	Wolf Creek Dam.....	40817-6649	X		29.10	.0047	10.4	6	6
7	16P-10	.....do.....	Cumberland City.....	40813-6706	X		26.30	.0046	---	11	--
8	16N-2	Cumberland, Ky....	Waterview.....	40801-6439	X		25.80	.0045	---	29	--
9	16N-3	.....do.....	Dubre.....	40716-6317	X		21.80	.0052	---	29	--
10	16N-11	.....do.....	Waterview.....	40724-6451	X		26.40	.0039	---	11	--
11	15K-14	Allen, Ky.....	Adulphus.....	40584-5664	X		11.00	.0056	---	29	--
12	15K-10	.....do.....	Holland.....	40591-5852	X		16.00	.0055	---	29	--
13	13B-1	Benton, Tenn.....	Camden.....	39888-4025	X		16.60	.0046	---	29	--
14	11C-4	Perry, Tenn.....	Linden.....	39418-4243	X		7.25	.0046	---	29	--
15	13F-7	Cheatham, Tenn....	Lillamay.....	40087-4968	X		13.45	.0055	---	29	--
16	13F-9	.....do.....	Kingston Springs.....	39965-4927	X		13.00	.0049	---	29	--
17	13F-22	Davidson, Tenn....	.....do.....	39859-4971	X		11.65	.0059	---	29	--
18	13G-12	.....do.....	Bellevue.....	39954-5050	X		14.90	.0040	---	29	--
19	NV-53	.....do.....	.....do.....	39959-5021		X	13.36	.0053	---	6	--
20	13G-2	.....do.....	Scottsboro.....	40104-5071	X		12.10	.0057	---	29	--
21	NV-54	.....do.....	Whites Creek.....	40127-5112		X	11.56	.0060	---	6	--
22	13G-8	.....do.....	.....do.....	40126-5117	X		7.65	.0056	---	29	--
23	14G-6	.....do.....	.....do.....	40185-5153	X		14.70	.0050	---	29	--
24	14G-5	.....do.....	.....do.....	40164-5219	X		8.10	.0056	---	6	--
25	14G-14	.....do.....	.....do.....	40251-5216	X		10.70	.0061	---	6	--
26	NV-55	.....do.....	.....do.....	40253-5221		X	10.62	.0056	---	6	--
27	14H-1	Sumner, Tenn.....	White House.....	40272-5278	X		9.70	.0055	---	29	--
28	NV-56	.....do.....	Cottontown.....	40277-5370		X	9.67	.0056	7.7	6	27
29	NV-63	.....do.....	.....do.....	40284-5363		X	10.00	.0058	---	6	--
30	NV-62	.....do.....	.....do.....	40289-5361		X	8.71	.0060	---	6	--
31	14H-4	.....do.....	White House.....	40302-5330	X		10.00	.0051	---	6	--
32	14H-3	.....do.....	Cottontown.....	40369-5419	X		10.30	.0052	---	29	--
33	NV-57	.....do.....	Gallatin.....	40366-5462		X	11.23	.0052	---	6	--
34	14J-13	.....do.....	.....do.....	40349-5513	X		11.80	.0058	---	29	--
35	15J-15	.....do.....	Turners Station.....	40410-5571	X		16.30	.0055	---	29	--
36	NV-58	.....do.....	Hartsville.....	40356-5675		X	16.62	.0044	---	6	--
37	15K-11	.....do.....	Westmoreland.....	40455-5697	X		12.80	.0052	---	29	--
38	15K-8	Macon, Tenn.....	Lafayette.....	40492-5789	X		15.60	.0045	---	6	--
39	15K-6	.....do.....	.....do.....	40424-5795	X		13.90	.0059	---	29	--
40	15K-3	.....do.....	.....do.....	40412-5860	X		13.30	.0058	---	29	--
41	15L-9	.....do.....	Galen.....	40484-5916	X		15.70	.0056	---	29	--
42	15L-6	.....do.....	.....do.....	40524-5998	X		16.50	.0062	---	29	--
43	NV-61	.....do.....	.....do.....	40527-6000		X	15.57	.0052	---	6	--
44	15L-5	.....do.....	.....do.....	40460-6006	X		14.70	.0052	---	29	--
45	15L-4	.....do.....	.....do.....	40417-5956	X		14.90	.0062	---	6	--

See footnotes at end of table.

TABLE A-1. - Sample data, uranium content, and oil yield of the Gassaway Member, Chattanooga Shale--Continued

Locality No.		Location			Sample type		Thickness, feet	Assay[3]		Assay reference[4]	
This report	Field[1]	County, State	Quadrangle (7-1/2 minute)	UTM[2] coordinate, zone 16	Out-crop	Drill hole		Uranium, percent	Oil, gal/ton	Uranium	Oil
46	NV-59	Macon, Tenn.....	Pleasant Shade.....	40379-5899		X	15.67	0.0040	---	6	--
47	14L-10	.....do.....	.....do.....	40344-5944	X		14.75	.0046	---	29	--
48	14L-1	.....do.....	.....do.....	40315-5973	X		15.67	.0041	---	11	--
49	T-70	Smith, Tenn.....	.....do.....	40302-5982	X		13.65	.0054	---	26	--
50	14L-5	Macon, Tenn.....	Willette.....	40326-6045	X		13.25	.0051	8.5	27	27
51	NV-60	.....do.....	.....do.....	40336-6042		X	13.97	.0055	---	6.	--
52	15L-10	Clay, Tenn.....	Red Boiling Springs..	40406-6074	X		16.00	.0053	---	6	--
53	14M-13	Jackson, Tenn.....	Whitleyville.....	40383-6202	X		13.82	.0058	---	11	--
54	T-81	Clay, Tenn.....	Union Hill.....	40444-6212	X		19.05	.0057	---	32	--
55	15N-12	.....do.....	Dale Hollow Dam.....	40447-6383	X		17.65	.0053	5.6	6	6
56	14M-10	.....do.....	Burristown.....	40381-6283	X		7.91	.0043	---	11	--
57	14N-4	Overton, Tenn.....	Hilham.....	40369-6415	X		8.82	.0058	---	11	--
58	14N-3	.....do.....	Windle.....	40179-6369	X		18.63	.0040	---	6	--
59	T-194	Putnam, Tenn.....	.....do.....	40181-6377	X		18.10	.0050	---	26	--
60	14M-14	Jackson, Tenn.....	Dodson Branch.....	40170-3282	X		20.71	.0052	---	6	--
61	14M-9	.....do.....	.....do.....	40228-6300	X		15.61	.0038	---	6	--
62	14M-16	.....do.....	Burristown.....	40293-6286	X		17.82	.0046	6.3	6	6
63	14M-7	.....do.....	Whitleyville.....	40286-6233	X		8.17	.0048	---	11	--
64	14M-6	.....do.....	.....do.....	40282-6135	X		12.62	.0046	---	6	--
65	14M-8	.....do.....	Gainesboro.....	40222-6215	X		14.78	.0044	---	6	--
66	T-25	.....do.....	.....do.....	40209-6204	X		15.50	.0049	---	26	--
67	14M-15	.....do.....	.....do.....	40207-6183	X		15.98	.0037	---	6	--
68	14M-11	.....do.....	.....do.....	40173-6143	X		12.50	.0050	---	11	--
69	T-127	.....do.....	.....do.....	40155-6206	X		19.55	.0062	---	26	--
70	14M-2	.....do.....	.....do.....	40139-6234	X		17.34	.0046	---	6	--
71	YB-51	.....do.....	Cookeville West.....	40123-6288		X	16.89	.0050	---	6	--
72	13M-23	Putnam, Tenn.....	Baxter.....	40081-6212	X		15.24	.0054	9.5	11	27
73	T-19	.....do.....	.....do.....	40079-6215	X		16.35	.0059	---	26	--
74	13M-24	.....do.....	.....do.....	40061-6154	X		15.93	.0058	---	6	--
75	13L-22	Smith, Tenn.....	Buffalo Valley.....	40075-6045	X		16.79	.0040	7.9	27	27
76	T-66	.....do.....	.....do.....	40074-6048	X		13.45	.0050	---	26	--
77	13L-8	.....do.....	.....do.....	40043-6090	X		12.05	.0052	---	11	--
78	13L-17	Putnam, Tenn.....	Baxter.....	40027-6124	X		6.01	.0035	---	11	--
79	13M-19	.....do.....	.....do.....	40007-6169	X		17.25	.0053	---	11	--
80	YB-52	.....do.....	.....do.....	39988-6233		X	9.73	.0055	---	6	--
81	13M-7	.....do.....	Silver Point.....	39982-6217	X		19.58	.0053	9.5	6	6
82	T-93	.....do.....	.....do.....	39979-6215	X		15.95	.0052	---	26	--
83	13L-11	.....do.....	Center Hill Dam.....	39947-6108	X		14.39	.0059	5.2	6	6
84	13M-10	.....do.....	Silver Point.....	39931-6192	X		18.55	.0061	---	11	--
85	13M-1	.....do.....	Burgess Falls.....	39916-6281	X		21.51	.0045	11.1	6	6
86	13M-5	DeKalb, Tenn.....	Silver Point.....	39854-6176	X		14.84	.0061	---	11	--
87	13L-20	.....do.....	.....do.....	39858-6127	X		15.94	.0063	---	11	--
88	T-6	.....do.....	.....do.....	39866-6134	X		18.25	.0064	---	26	--
89	13M-30	.....do.....	.....do.....	39876-6137	X		15.22	.0066	---	6	--
90	13M-32	.....do.....	.....do.....	39902-6126	X		15.23	.0061	---	6	--

See footnotes at end of table.

TABLE A-1. - Sample data, uranium content, and oil yield of the Gassaway Member, Chattanooga Shale--Continued

Locality No.		Location			Sample type		Thickness,	Assay[3]		Assay reference[4]	
This report	Field[1]	County, State	Quadrangle (7-1/2 minute)	UTM[2] coordinate, zone 16	Out-crop	Drill hole	feet	Uranium, percent	Oil, gal/ton	Uranium	Oil
91	T-88	DeKalb, Tenn.....	Center Hill Dam.....	39895-6122	X		16.80	0.0065	---	32	--
92	T-211	.....do.....	.....do.....	39938-6016	X		13.45	.0062	---	32	--
93	13L-13	.....do.....	Liberty.....	39905-6003	X		11.14	.0060	---	6	--
94	T-213	.....do.....	.....do.....	39862-5993	X		13.25	.0056	---	32	--
95	LC-34	.....do.....	Gassaway.....	39837-5982	X		13.33	.0052	---	11	--
96	T-113	.....do.....	.....do.....	39837-5990	X		13.85	.0052	---	32	--
97	T-104	.....do.....	.....do.....	39773-5936	X		11.50	.0055	---	32	--
98	RC-5	.....do.....	.....do.....	39774-5939	X		11.50	.0064	---	6	--
99	YB-33	.....do.....	.....do.....	39781-5964		X	12.09	.0056	---	6	--
100	YB-34	.....do.....	.....do.....	39769-5946		X	11.91	.0059	---	6	--
101	YB-35	.....do.....	.....do.....	39755-5946		X	11.01	.0057	---	6	--
102	YB-36	.....do.....	.....do.....	39747-5952		X	11.25	.0056	---	6	--
103	T-206	.....do.....	.....do.....	39718-5972	X		11.55	.0056	---	32	--
104	RC-7	.....do.....	.....do.....	39712-5980	X		11.08	.0048	---	11	--
105	YB-28	.....do.....	.....do.....	39756-5991		X	11.97	.0062	---	6	--
106	T-204	.....do.....	.....do.....	39768-6003	X		13.90	.0061	---	32	--
107	YB-27	.....do.....	.....do.....	39769-6012		X	14.96	.0066	---	6	--
108	YB-29	.....do.....	.....do.....	39759-6013		X	14.81	.0055	---	6	--
109	RC-8	.....do.....	Smithville.....	39805-6016	X		12.72	.0059	---	6	--
110	YB-26	.....do.....	.....do.....	39770-6029		X	14.07	.0066	---	6	--
111	YB-30	.....do.....	.....do.....	39751-6025		X	12.71	.0060	---	6	--
112	YB-31	.....do.....	.....do.....	39747-6046		X	14.35	.0060	---	6	--
113	YB-25	.....do.....	.....do.....	39769-6045		X	12.38	.0060	---	6	--
114	LC-15	.....do.....	.....do.....	39822-6064	X		15.09	.0055	7.0	27	27
115	YB-39	.....do.....	.....do.....	39829-6092		X	15.47	.0054	---	6	--
116	LC-101	.....do.....	.....do.....	39782-6067		X	7.50	.0073	9.5	6	27
117	YB-24	.....do.....	.....do.....	39771-6065		X	14.81	.0061	---	6	--
118	YB-32	.....do.....	.....do.....	39749-6064		X	14.38	.0065	---	6	--
119	LC-103	.....do.....	.....do.....	39741-6067		X	14.70	.0065	10.6	6	27
120	LC-105	.....do.....	.....do.....	39716-6099		X	14.00	.0059	10.8	6	27
121	YB-20	.....do.....	.....do.....	39753-6081		X	13.64	.0058	---	6	--
122	YB-23	.....do.....	.....do.....	39768-6080		X	13.97	.0060	---	6	--
123	YB-22	.....do.....	.....do.....	39762-6092		X	16.05	.0063	---	6	--
124	YB-19	.....do.....	.....do.....	39754-6097		X	14.25	.0061	---	6	--
125	YB-18	.....do.....	.....do.....	39762-6105		X	15.10	.0063	---	6	--
126	YB-21	.....do.....	.....do.....	39773-6101		X	14.84	.0059	---	6	--
127	LC-12	.....do.....	.....do.....	39780-6106	X		10.32	.0063	---	11	--
128	LC-17	.....do.....	.....do.....	39807-6124	X		16.91	.0056	---	11	--
129	YB-17	.....do.....	.....do.....	39771-6119		X	14.79	.0062	---	6	--
130	YB-14	.....do.....	.....do.....	39763-6123		X	14.52	.0056	---	6	--
131	YB-16	.....do.....	.....do.....	39754-6111		X	14.59	.0059	---	6	--
132	LC-30	.....do.....	.....do.....	39749-6118	X		15.19	.0048	---	6	--
133	YB-15	.....do.....	.....do.....	39749-6127		X	14.45	.0063	---	6	--
134	PC-3	.....do.....	Sligo Bridge.....	39749-6133		X	14.73	.0068	---	6	--
135	PC-2	.....do.....	.....do.....	39749-6134		X	14.78	.0061	---	6	--

See footnotes at end of table.

TABLE A-1. - Sample data, uranium content, and oil yield of the Gassaway Member, Chattanooga Shale--Continued

Locality No.		Location			Sample type		Thickness,	Assay[3]		Assay reference[4]	
This report	Field[1]	County, State	Quadrangle (7-1/2 minute)	UTM[2] coordinate, zone 16	Out-crop	Drill hole	feet	Uranium, percent	Oil, gal/ton	Uranium	Oil
136	PC-1	DeKalb, Tenn.....	Sligo Bridge.....	39746-6134		X	15.15	0.0062	---	6	--
137	YB-9	.....do.....	.....do.....	39754-6139		X	15.04	.0060	---	6	--
138	YB-10	.....do.....	.....do.....	39760-6138		X	14.93	.0059	---	6	--
139	YB-13	.....do.....	.....do.....	39771-6133		X	15.12	.0061	---	6	--
140	YB-11	.....do.....	.....do.....	39770-6144		X	16.25	.0056	---	6	--
141	YB-12	.....do.....	.....do.....	39775-6154		X	16.65	.0061	---	6	--
142	T-12	.....do.....	.....do.....	39764-6148	X		18.40	.0061	---	26	--
143	YB-7	.....do.....	.....do.....	39761-6155		X	15.69	.0058	---	6	--
144	YB-6	.....do.....	.....do.....	39767-6161		X	16.91	.0058	---	6	--
145	LC-50	.....do.....	.....do.....	39771-6161	X		18.29	.0059	---	6	--
146	YB-4	.....do.....	.....do.....	39770-6168		X	17.83	.0061	---	6	--
147	YB-3	.....do.....	.....do.....	39770-6181		X	14.47	.0054	---	6	--
148	YB-2	.....do.....	.....do.....	39774-6176		X	17.50	.0061	---	6	--
149	YB-1	.....do.....	.....do.....	39781-6181		X	15.40	.0062	---	6	--
150	LC-1	.....do.....	.....do.....	39800-6153	X		16.30	.0064	---	11	--
151	LC-56	.....do.....	.....do.....	39806-6155	X		16.40	.0060	---	11	--
152	LC-2	.....do.....	.....do.....	39807-6152	X		16.60	.0065	---	11	--
153	LC-10	.....do.....	.....do.....	39803-6166	X		18.45	.0061	4.5	11	27
154	LC-102	.....do.....	.....do.....	39808-6166		X	15.45	.0058	9.7	6	27
155	LC-55	.....do.....	.....do.....	39809-6163	X		16.60	.0063	---	11	--
156	LC-4	.....do.....	.....do.....	39818-6163	X		18.23	.0062	---	6	--
157	YB-38	.....do.....	.....do.....	39762-6195		X	16.17	.0060	---	6	--
158	LC-6	.....do.....	.....do.....	39743-6198	X		16.47	.0058	---	11	--
159	LC-8	.....do.....	.....do.....	39719-6195	X		17.44	.0072	---	11	--
160	LC-33	.....do.....	.....do.....	39718-6168	X		16.50	.0064	8.3	6	27
161	YB-40	.....do.....	.....do.....	39708-6131		X	14.74	.0058	---	6	--
162	13M-4	White, Tenn.....	Cassville.....	39844-6247	X		21.42	.0035	---	6	--
163	YB-37	.....do.....	Sligo Bridge.....	39809-6206		X	17.43	.0057	8.1	6	6
164	LC-51	.....do.....	.....do.....	39740-6227	X		16.95	.0061	---	11	--
165	LC-11	.....do.....	Campaign.....	39659-6193	X		13.42	.0057	9.6	27	27
166	LC-113	.....do.....	Lonewood.....	39642-6469		X	11.50	.0062	8.2	6	27
167	T-141	Warren, Tenn.....	Campaign.....	39657-6189	X		16.35	.0061	---	32	--
168	WR-50	Cumberland, Tenn..	Grassy Cove.....	39682-6881		X	21.04	.0070	1.9	6	6
169	12Q-1	Rhea, Tenn.....	Roddy.....	39614-7008	X		28.00	.0073	---	11	--
170	11P-1	.....do.....	Morgan Springs.....	39326-6806	X		11.90	.0060	---	6	--
171	RS-6	Bledsoe, Tenn.....	Melvine.....	39547-6797	X		15.47	.0061	---	6	--
172	WR-49	.....do.....	Pikeville.....	30388-6654		X	17.97	.0058	3.3	6	27
173	RS-17	.....do.....	Mount Airy.....	39223-6548	X		12.73	.0055	---	10	--
174	RS-1	Sequatchie, Tenn..	Daus.....	39077-6471	X		14.47	.0051	---	6	--
175	WR-48	.....do.....	.....do.....	39068-6462		X	15.07	.0069	.7	6	6
176	RS-2	Marion, Tenn.....	Ketner Gap.....	38941-6392	X		13.27	.0055	---	6	--
177	WR-47	.....do.....	.....do.....	38930-6390		X	10.89	.0066	---	6	--
178	RS-15	.....do.....	Sequatchie.....	38787-6291	X		8.76	.0054	---	6	--
179	10M-1	Grundy, Tenn.....	Tracy City.....	39150-6214		X	15.00	.0063	---	6	--
180	YB-46	Warren, Tenn.....	Cardwell Mountain....	39485-6174		X	16.40	.0066	---	6	--

See footnotes at end of table.

TABLE A-1. - Sample data, uranium content, and oil yield of the Gassaway Member, Chattanooga Shale--Continued

Locality No.		Location			Sample type		Thickness,	Assay[3]		Assay reference[4]	
This report	Field[1]	County, State	Quadrangle (7-1/2 minute)	UTM[2] coordinate, zone 16	Out-crop	Drill hole	feet	Uranium, percent	Oil, gal/ton	Uranium	Oil
181	YB-42	Warren, Tenn.....	Centertown.....	39487-5956		X	18.35	0.0062	4.8	6	6
182	T-214	Cannon, Tenn.....	Short Mountain.....	39658-5951	X		12.40	.0058	---	26	--
183	RC-4	.....do.....	.....do.....	39667-5945	X		14.05	.0073	9.6	6	6
184	T-149	.....do.....	Woodbury.....	39694-5899	X		13.70	.0063	---	26	--
185	LC-60	.....do.....	.....do.....	39697-5876	X		14.02	.0051	---	6	--
186	T-116	.....do.....	Auburntown.....	39713-5877	X		13.80	.0048	---	32	--
187	T-202	.....do.....	.....do.....	39737-5859	X		14.10	.0064	---	26	--
188	RC-6	.....do.....	Woodbury.....	39698-5815	X		13.35	.0056	7.8	6	27
189	RC-1	.....do.....	.....do.....	39610-5854	X		13.74	.0058	---	11	--
190	T-220	.....do.....	.....do.....	39620-5892	X		14.40	.0070	---	32	--
191	YB-41	.....do.....	Short Mountain.....	39597-5909		X	13.02	.0058	---	6	--
192	RC-2	.....do.....	Woodbury.....	39582-5844	X		12.26	.0055	4.5	6	27
193	T-317	.....do.....	.....do.....	39581-5839	X		12.05	.0063	---	26	--
194	T-321	.....do.....	Beech Grove.....	39513-5753	X		9.85	.0059	---	26	--
195	RC-3	.....do.....	.....do.....	39502-5761	X		9.70	.0054	---	6	--
196	YB-43	Coffee, Tenn.....	Beech Grove.....	39441-5747		X	11.27	.0057	---	6	--
197	11K-2	.....do.....	.....do.....	39438-5744	X		9.46	.0059	---	6	--
198	11K-1	.....do.....	Noah.....	39382-6722	X		12.78	.0063	4.7	6	27
199	T-335	.....do.....	.....do.....	39341-5702	X		12.30	.0068	---	26	--
200	YB-44	.....do.....	Ovoca.....	39285-5777		X	14.80	.0065	5.0	6	6
201	T-390	.....do.....	Manchester.....	39268-5813	X		15.85	.0079	---	32	--
202	T-387	.....do.....	Ovoca.....	39220-5755	X		13.55	.0076	---	32	--
203	10K-4	.....do.....	.....do.....	39217-5759	X		15.04	.0057	---	6	--
204	10K-5	.....do.....	.....do.....	39208-5689	X		13.64	.0051	3.9	6	6
205	10J-8	Moore, Tenn.....	Normandy.....	39178-5657	X		15.67	.0061	---	6	--
206	T-404	.....do.....	Cumberland Springs...	39129-5609	X		10.65	.0068	---	32	--
207	YB-45	.....do.....	.....do.....	39116-5638		X	12.35	.0068	---	6	--
208	10J-9	.....do.....	.....do.....	39108-5639	X		13.00	.0057	6.8	6	27
209	10K-11	Franklin, Tenn....	Tullahoma.....	39015-5783	X		9.40	.0042	---	11	--
210	10H-40	Bedford, Tenn.....	Belleville.....	39127-5435	X		8.50	.0066	---	29	--
211	T-417	Lincoln, Tenn.....	.....do.....	39127-5415	X		5.90	.0083	---	32	--
212	9H-49	.....do.....	Lincoln.....	38838-5393	X		4.55	.0076	---	29	--
213	9G-47	Giles, Tenn.....	Dellrose.....	38734-5119	X		3.60	.0087	---	29	--
214	10G-36	Marshall, Tenn....	Cornersville.....	39137-5132	X		4.65	.0065	---	29	--
215	12H-31	Williamson, Tenn..	College Grove.....	39565-5231	X		4.00	.0053	---	29	--
216	7P-2	Walker, Ga.....	Catlett.....	38398-6770	X		10.00	.0035	---	18	--
217	15L-1	De Kalb, Ala.....	Portersville.....	37921-6045	X		5.00	.0052	---	29	--
218	4J-2	Saint Clair, Ala..	Hyatt Gap.....	37484-5647	X		3.00	.0070	---	29	--
219	AL-64	Blount, Ala.....	Holly Pond.....	37799-5458		X	11.95	.0044	.7	6	27
220	AL-65	.....do.....	Blountsville.....	37737-5419		X	20.12	.0057	---	6	--
221	AL-66	.....do.....	.....do.....	37683-5348		X	33.60	.0054	---	6	--
222	4G-1	.....do.....	Blount Springs.....	37540-5195	X		26.00	.0065	---	18	--

1/ Locality numbers assigned by original investigators. Digits preceded by the letter "T" refer to localities investigated by the Department of Geology and Geography, University of Tennessee, Knoxville, Tenn. All other localities investigated by the U.S. Geological Survey.

2/ Universal Transverse Mercator grid. Coordinates are to the nearest northing 100-meter value and the nearest easting 100-meter value. Last two zeros for each value are omitted.

3/ Assay values are weighted means.

4/ Only one reference listed for each locality. Data may be found in more than one reference. See list of references on p. 38 of this report.

TABLE A-2. - Sample data, uranium content, and oil yield of the Maury Formation and Dowelltown Member, Chattanooga Shale

Locality No.		Maury Formation				Dowelltown Member, Chattanooga Shale			
		Thickness,	Assay[2]			Thickness,	Assay[2]		
This report	Field[1]	feet	Uranium, percent	Oil, gal/ton	Reference[3]	feet	Uranium, percent	Oil, gal/ton	Reference[3]
13	13B-1	---	---	---	--	11.00	0.0037	---	29
16	13F-9	0.7	0.006	---	29	---	---	---	--
19	NV-53	1.10	.0030	---	29	4.06	---	---	6
21	NV-54	1.61	.0016	---	29	13.49	---	---	6
26	NV-55	1.63	.0006	---	29	15.92	---	---	29
28	NV-56	1.42	.0013	---	6	13.15	.0009	6.5	27
30	NV-62	.88	.0022	---	29	8.05	---	---	6
33	NV-57	1.00	.0020	---	6	10.69	---	---	6
36	NV-58	.30	.0017	---	29	12.34	.0012	---	6
43	NV-61	3.27	.0005	---	29	5.86	.0011	---	6
46	NV-59	.33	.0002	---	29	3.31	---	---	6
50	14L-5	2.00	.0025	2.9	27	5.41	---	---	6
51	NV-60	2.75	.0007	---	29	3.67	.0020	---	6
54	T-81	.75	---	---	32	2.90	.0027	---	32
55	15N-12	1.35	---	---	32	1.18	.0021	---	32
60	14M-14	---	---	---	--	6.92	.0013	---	6
61	14M-9	2.00	---	---	32	4.98	.0010	---	6
62	14M-16	1.20	---	---	32	4.00	.0016	---	6
65	14M-8	---	---	---	--	5.50	.0018	---	6
71	YB-51	1.30	.0011	---	6	---	---	---	--
72	13M-23	2.69	.0042	3.7	27	9.58	---	---	11
75	13L-22	3.19	.0013	---	27	11.33	.0023	---	11
80	YB-52	2.17	.0047	---	6	13.06	---	---	6
81	13M-7	2.10	.0022	6.1	27	10.96	---	---	11
82	T-93	1.50	---	---	32	11.50	.0018	---	32
83	13L-11	4.45	.0024	1.4	27	14.12	---	---	11
84	13M-10	1.50	.0020	---	11	14.56	.0019	---	11
85	13M-1	2.70	.0019	11.0	27	13.62	---	---	11
86	13M-5	---	---	---	--	14.93	.0019	---	11
95	LC-34	1.34	.0040	---	11	13.02	---	---	11
99	YB-33	3.10	.0003	---	6	13.33	---	---	6
100	YB-34	3.43	.0004	---	6	13.77	---	---	6
101	YB-35	3.19	.0020	---	6	13.91	---	---	6
102	YB-36	3.06	.0008	---	6	13.67	---	---	6
105	YB-28	3.20	.0005	---	6	13.73	---	---	6
107	YB-27	2.94	.0011	---	6	14.09	---	---	6
108	YB-29	3.90	.0005	---	6	14.62	---	---	6
110	YB-26	2.92	.0008	---	6	14.04	---	---	6
111	YB-30	2.45	.0015	---	6	14.25	---	---	6
112	YB-31	1.97	.0028	---	6	14.53	---	---	6
113	YB-25	2.25	.0015	---	6	13.87	---	---	6
114	LC-15	.50	.0034	.5	27	15.08	.0038	---	11
115	YB-39	3.77	.0006	---	6	15.29	.0018	---	6
117	YB-24	2.41	.0004	---	6	14.85	---	---	6
118	YB-32	2.08	.0016	---	6	15.22	---	---	6
119	LC-103	.50	.0020	---	6	15.40	.0019	4.4	6
120	LC-105	1.25	.0010	---	11	15.45	.0019	5.8	6
121	YB-20	2.27	.0021	---	6	14.95	---	---	6
122	YB-23	2.50	.0009	---	6	15.55	---	---	6
123	YB-22	2.28	.0008	---	6	15.85	---	---	6
124	YB-19	1.80	.0015	---	6	15.36	---	---	6
125	YB-18	2.26	.0002	---	6	15.85	---	---	6
126	YB-21	2.03	.0009	---	6	15.34	---	---	6
128	LC-17	1.97	.0020	---	11	15.24	.0050	---	11
129	YB-17	2.26	.0007	---	6	15.52	---	---	6
130	YB-14	2.07	.0007	---	6	---	---	---	--
131	YB-16	1.60	.0005	---	6	15.52	.0017	---	6
132	LC-30	1.88	.0020	---	11	12.78	.0031	---	11
133	YB-15	2.05	.0010	---	6	15.30	.0019	---	6

See footnotes at end of table.

TABLE A-2. - Sample data, uranium content, and oil yield of the Maury Formation and Dowelltown Member, Chattanooga Shale--Continued

Locality No.		Maury Formation				Dowelltown Member, Chattanooga Shale			
This report	Field 1/	Thickness, feet	Assay 2/ Uranium, percent	Assay 2/ Oil, gal/ton	Reference 3/	Thickness, feet	Assay 2/ Uranium, percent	Assay 2/ Oil, gal/ton	Reference 3/
137	YB-9	1.43	0.0009	---	6	15.35	---	---	6
138	YB-10	1.92	.0018	---	6	15.42	0.0018	---	6
139	YB-13	1.51	.0023	---	6	13.50	---	---	6
140	YB-11	1.65	.0007	---	6	16.91	.0019	---	6
141	YB-12	1.34	.0003	---	6	16.71	.0018	---	6
142	T-12	1.55	---	---	32	19.15	.0011	---	32
143	YB-7	1.01	.0030	---	6	17.33	.0019	---	6
144	YB-6	1.48	.0011	---	6	16.90	.0019	---	6
145	LC-50	1.80	.0030	---	11	17.81	.0033	---	11
146	YB-4	1.77	.0008	---	6	18.16	.0016	---	6
147	YB-3	1.43	.0013	---	6	16.07	.0019	---	6
148	YB-2	1.45	.0004	---	6	17.00	.0031	---	6
149	YB-1	1.57	.0024	---	6	17.45	.0021	---	6
150	LC-1	1.20	.0020	---	11	15.70	.0031	---	11
151	LC-56	2.15	---	---	32	15.30	.0023	---	32
152	LC-2	.90	.0020	---	11	16.64	.0037	---	11
153	LC-10	2.06	.0020	---	11	14.50	.0026	---	11
154	LC-102	.75	.0023	0.7	27	15.35	.0017	5.1	27
155	LC-55	1.80	---	---	11	15.50	.0019	---	32
156	LC-4	1.12	.0020	---	11	16.54	.0038	---	11
157	YB-38	1.28	.0005	---	6	17.28	.0017	---	6
158	LC-6	.95	.0040	---	11	17.37	.0035	---	11
160	LC-33	1.37	---	---	11	16.90	.0043	---	11
161	YB-40	2.93	.0013	---	6	17.60	.0020	---	6
163	YB-37	1.35	.0018	---	6	16.66	.0019	4.1	6
165	LC-11	2.03	.0040	---	11	8.19	.0025	---	11
166	LC-113	---	---	---	--	10.40	.0013	3.8	27
168	WR-50	2.70	.0007	---	6	13.85	.0015	---	6
169	12Q-1	1.60	.0020	---	11	7.40	.0053	---	11
172	WR-49	2.57	.0003	---	6	---	---	---	--
175	WR-48	2.56	.0004	---	6	---	---	---	--
177	WR-47	2.71	.0013	---	6	---	---	---	--
179	10M-1	2.00	.0120	---	11	8.00	---	---	6
180	YB-46	1.42	.0020	---	6	15.79	.0018	---	6
181	YB-42	2.53	.0006	---	6	14.64	.0018	---	6
188	RC-6	2.40	---	---	32	15.30	.0024	---	32
191	YB-41	3.57	.0005	---	6	13.42	.0022	---	6
195	RC-3	---	---	---	--	16.29	.0021	---	6
200	YB-44	2.45	.0015	---	6	14.66	.0020	3.5	27
203	10K-4	---	---	---	--	6.27	.0033	---	11
205	10J-8	---	---	---	--	5.05	.0026	---	11
207	YB-45	.95	.0017	---	6	---	---	---	--
219	AL-64	4.60	.0004	---	15	7.40	.0019	1.2	6
220	AL-65	6.10	.0014	---	29	---	---	---	--
221	AL-66	2.24	.0025	---	29	8.95	.0016	---	6

1/ Locality numbers assigned by original investigators. Digits preceded by the letter "T" refer to localities investigated by the Department of Geology and Geography, University of Tennessee, Knoxville, Tenn. All other localities investigated by the U.S. Geological Survey.

2/ Assay values are weighted means.

3/ Only one reference listed for each locality. Data may be found in more than one reference. See list of references on p. 38 of this report.

TABLE A-3. - Locality cross-reference list

Locality No. Field	This report	Locality No. Field	This report	Locality No. Field	This report	Locality No. Field	This report
4G-1	222	14M-11	68	NV-54	21	T-317	193
4J-2	218	14M-13	53	NV-55	26	T-321	194
7P-2	217	14M-14	60	NV-56	28	T-335	199
9G-47	213	14M-15	67	NV-57	33	T-3B7	202
9H-49	212	14M-16	62	NV-5B	36	T-390	201
10G-36	214	14N-3	58	NV-59	46	T-404	206
10H-40	210	14N-4	57	NV-60	51	T-417	211
10J-8	205	15J-15	35	NV-61	43	WR-47	177
10J-9	208	15K-3	40	NV-62	30	WR-48	175
10K-4	203	15K-6	39	NV-63	29	WR-49	172
10K-5	204	15K-8	3B	PC-1	136	WR-50	16B
10K-11	209	15K-10	12	PC-2	135	YB-1	149
10M-1	179	15K-11	37	PC-3	134	Y8-2	14B
11C-4	14	15K-14	11	RC-1	189	YB-3	147
11K-1	198	15L-1	216	RC-2	192	YB-4	146
11K-2	197	15L-4	45	RC-3	195	Y8-6	144
11P-1	170	15L-5	44	RC-4	183	YB-7	143
12H-31	215	15L-6	42	RC-5	98	YB-9	137
12Q-1	169	15L-9	41	RC-6	188	YB-10	138
13B-1	13	15L-10	52	RC-7	104	Y8-11	140
13F-7	15	15N-12	55	RC-B	109	YB-12	141
13F-9	16	16N-2	B	R5-1	174	YB-13	139
13F-22	17	16N-3	9	R5-2	176	YB-14	130
13G-2	20	16N-11	10	R5-6	171	YB-15	133
13G-B	22	16P-1	6	R5-15	178	YB-16	131
13G-12	18	16P-10	7	R5-17	173	Y8-17	129
13L-8	77	17P-B	2	T-1	155	YB-18	125
13L-11	B3	17Q-4	5	T-2	151	YB-19	124
13L-13	93	17R-6	3	T-3	114	YB-20	121
13L-17	78	17R-9	4	T-6	88	YB-21	126
13L-20	B7	18N-12	1	T-12	142	Y8-22	123
13L-22	75	AL-64	219	T-19	73	YB-23	122
13M-1	85	AL-65	220	T-22	83	YB-24	117
13M-4	162	AL-66	221	T-25	66	Y8-25	113
13M-5	86	LC-1	150	T-31	61	Y8-26	110
13M-7	81	LC-2	152	T-36	62	Y8-27	107
13M-10	84	LC-4	156	T-43	68	YB-2B	105
13M-19	79	LC-6	158	T-66	76	YB-29	108
13M-23	72	LC-8	159	T-70	49	Y8-30	111
13M-24	74	LC-10	153	T-72	55	Y8-31	112
13M-30	B9	LC-11	165	T-81	54	Y8-32	11B
13M-32	90	LC-12	127	T-BB	91	YB-33	99
14G-5	24	LC-15	114	T-93	82	Y8-34	100
14G-6	23	LC-17	128	T-104	97	YB-35	101
14G-14	25	LC-30	132	T-113	96	YB-36	102
14H-1	27	LC-33	160	T-116	186	YB-37	163
14H-3	32	LC-34	95	T-127	69	Y8-38	157
14H-4	31	LC-50	145	T-141	167	Y8-39	115
14J-13	34	LC-51	164	T-147	188	Y8-40	161
14L-1	4B	LC-55	155	T-149	184	YB-41	191
14L-5	50	LC-56	151	T-194	59	YB-42	181
14L-10	47	LC-60	185	T-202	187	YB-43	196
14M-2	70	LC-101	116	T-204	106	YB-44	200
14M-6	64	LC-102	154	T-206	103	YB-45	207
14M-7	63	LC-103	119	T-211	92	Y8-46	180
14M-8	65	LC-105	120	T-213	94	YB-51	71
14M-9	61	LC-113a	166	T-214	182	YB-52	B0
14M-10	56	NV-53	19	T-220	190		

FIGURE A-1

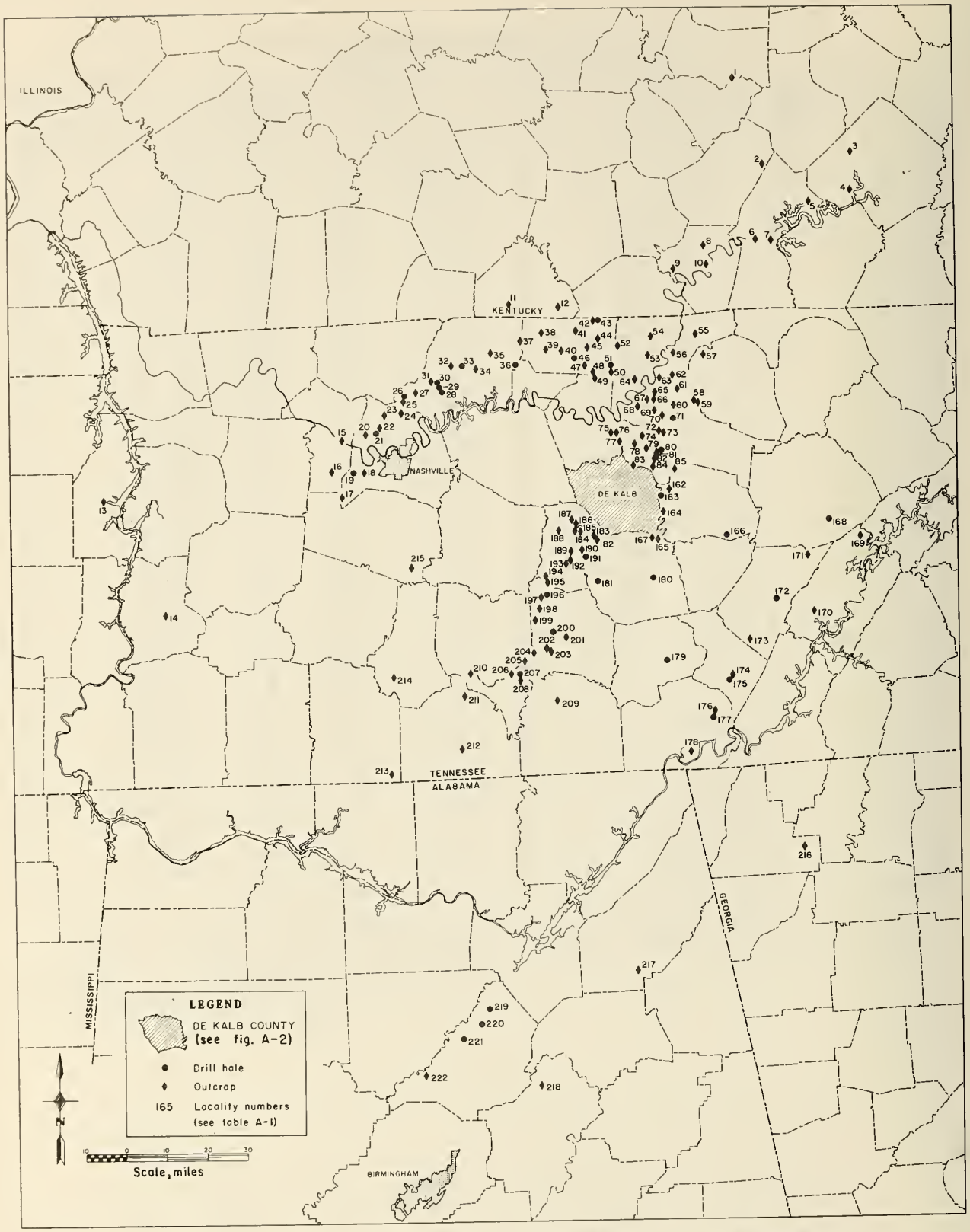

FIGURE A-1. - Sample localities in Tennessee and adjacent areas.

FIGURE A-2

FIGURE A-2. - Sample localities in DeKalb County, Tenn.

APPENDIX B.--OTHER ANALYSES

TABLE B-1. - Mineralogical and chemical composition of the Gassaway Member, Chattanooga Shale[1/]

	Locality No. 21 (drill hole NV-54)			Locality No. 30 (drill hole NV-62)			Locality No. 46 (drill hole NV-59)		
	Mean($\bar{x}$), percent	Standard deviation(s)	Number of samples[2/]	Mean($\bar{x}$), percent	Standard deviation(s)	Number of samples[2/]	Mean($\bar{x}$), percent	Standard deviation(s)	Number of samples[2/]
Total Iron.....	8.45	4.32	15	6.66	1.22	8	5.77	1.52	28
Ferric Iron.....	.96	.12	15	.69	.07	8	.69	.10	28
Iron Sulfide (pyrite).....	16.10	9.35	15	12.82	2.68	8	10.91	3.15	28
Iron Oxides.....	1.37	.17	15	1.00	.11	8	.98	.15	28
Iron Carbonate (siderite)...	2.19	4.91	15	.80	.45	8	1.07	1.26	28
Total Carbon.....	11.45	1.58	15	11.48	.87	8	12.33	3.08	28
Carbonate Carbon (CO_2).....	.96	2.16	15	.35	.20	8	.47	.55	28
Organic Carbon.....	11.19	2.01	15	11.38	.89	8	12.21	3.13	28
Aromatic Hydrocarbons.....	---	---	--	---	---	--	.50	.47	26
Aliphatic Hydrocarbons.....	---	---	--	---	---	--	13.55	3.41	26
Total Silicates.....	61.69	7.49	15	64.42	2.90	8	64.99	5.14	28
Quartz.....	---	---	--	---	---	--	22.33	3.32	26
Kaolinite.....	---	---	--	---	---	--	3.34	.83	26
Illite.....	---	---	--	---	---	--	24.60	11.67	26
Amorphous Silicates.....	---	---	--	---	---	--	15.16	10.38	26
Hydrogen.....	---	---	--	---	---	--	1.55	.29	28
Molybdenum.....	---	---	--	---	---	--	.017	.011	26
Manganese.....	---	---	--	---	---	--	.026	.021	26

See footnotes at end of table.

TABLE B-1. - Mineralogical and chemical composition of the Gassaway Member, Chattanooga Shale[1/] --Continued

	Locality No. 51 (drill hole NV-60)			Locality No. 140 (drill hole YB-11)			Locality No. 177 (drill hole WR-47)		
	Mean($\bar{x}$), percent	Standard deviation(s)	Number of samples[2/]	Mean($\bar{x}$), percent	Standard deviation(s)	Number of samples[2/]	Mean($\bar{x}$), percent	Standard deviation(s)	Number of samples[2/]
Total Iron.....	4.68	1.63	29	4.91	1.27	30	4.44	1.71	13
Ferric Iron.....	.66	.12	29	.67	.14	30	.42	.27	13
Iron Sulfide (pyrite).....	8.60	3.51	29	9.11	2.84	30	8.62	3.51	13
Iron Oxides.....	.96	.12	29	.96	.21	30	.61	.39	13
Iron Carbonate (siderite)...	.46	.42	29	1.56	3.44	30	2.12	1.69	13
Total Carbon.....	12.44	3.27	29	13.18	4.35	30	11.03	3.15	13
Carbonate Carbon (CO_2).....	.20	.18	29	.69	1.51	30	.93	.74	13
Organic Carbon.....	12.39	3.27	29	12.99	4.54	30	10.78	3.25	13
Aromatic Hydrocarbons.....	.54	.40	26	.46	.33	11	---	---	--
Aliphatic Hydrocarbons.....	13.80	3.50	26	16.19	6.80	11	---	---	--
Total Silicates.....	71.04	6.00	29	66.84	6.40	30	66.17	9.11	13
Quartz.....	21.86	4.00	26	28.35	6.53	13	---	---	--
Kaolinite.....	3.40	.68	26	2.92	.41	13	---	---	--
Illite.....	29.40	9.41	26	22.22	10.30	13	---	---	--
Amorphous Silicates.....	15.94	9.12	26	13.52	7.52	13	---	---	--
Hydrogen.....	1.58	.24	29	1.68	.37	30	---	---	--
Molybdenum.....	.016	.007	26	.014	.007	12	---	---	--
Manganese.....	.031	.016	26	.032	.010	12	---	---	--

See footnotes at end of table.

TABLE B-1. - Mineralogical and chemical composition of the Gassaway Member, Chattanooga Shale[1/] --Continued

	Locality No. 200 (drill hole YB-44)			Locality No. 207 (drill hole YB-45)			Locality No. 219 (drill hole AL-64)		
	Mean($\bar{x}$), percent	Standard deviation(s)	Number of samples[2/]	Mean($\bar{x}$), percent	Standard deviation(s)	Number of samples[2/]	Mean($\bar{x}$), percent	Standard deviation(s)	Number of samples[2/]
Total Iron.....	5.85	2.42	15	3.83	2.36	10	2.97	1.01	19
Ferric Iron.....	.83	.26	15	.76	.07	10	.50	.18	19
Iron Sulfide (pyrite).....	10.79	5.51	15	6.59	5.10	10	5.30	2.36	19
Iron Oxides.....	1.19	.38	15	1.08	.10	10	.72	.26	19
Iron Carbonate (siderite)...	.99	.80	15	.84	.70	10	5.14	6.04	19
Total Carbon.....	12.06	2.76	15	12.24	2.22	10	6.33	2.74	19
Carbonate Carbon (CO_2).....	.44	.35	15	.37	.30	10	2.26	2.66	19
Organic Carbon.....	11.94	2.74	15	12.14	2.18	10	5.71	3.17	19
Aromatic Hydrocarbons.....	---	---	--	---	---	--	.23	.23	17
Aliphatic Hydrocarbons.....	---	---	--	---	---	--	3.68	1.80	17
Total Silicates.....	70.01	6.01	15	64.94	6.71	10	77.80	5.58	19
Quartz.....	---	---	--	---	---	--	37.45	9.24	17
Kaolinite.....	---	---	--	---	---	--	3.39	.62	17
Illite.....	---	---	--	---	---	--	19.24	10.30	17
Amorphous Silicates.....	---	---	--	---	---	--	18.07	9.20	17
Hydrogen.....	---	---	--	---	---	--	---	---	--
Molybdenum.....	---	---	--	---	---	--	.066	.032	17
Manganese.....	---	---	--	---	---	--	.075	.030	17

1/ Analyses from selected localities as reported. Uranium values deleted.
2/ Randomly chosen samples of unknown length.

Source for Chattanooga Shale analyses: Bates, T. F., E. O. Strahl, and R. L. O'Neil (1).

TABLE B-2. - Chemical analyses other than uranium and oil for the Gassaway and Dowelltown Members, Chattanooga Shale[1/]

Locality No.		Member[3/]	Thickness,	Analyses, percent											Loss on
This report	Field[2/]		feet	K_2O	P_2O_5	S[4/]	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	TiO_2	MnO	ignition
1	18N-12	G	30.0	3.62	0.14	3.44	54.5	12.3	6.7	0.9	0.15	0.41	0.67	0.01	20.4
28	NV-56	G	9.67	3.69	.27	8.76	47.4	11.1	11.6	1.1	.25	.36	.68	.01	23.8
		D	13.15	4.45	.23	1.75	55.9	14.0	4.0	2.8	2.7	.47	.78	.03	13.3
50	14L-5	G	13.25	---	1.07	9.62	---	---	---	---	---	---	---	---	---
55	15N-12	G	17.65	3.48	.71	4.58	54.1	12.1	7.5	1.2	.58	.40	.80	.02	19.6
		D	1.18	4.4	.24	---	57.8	14.0	4.5	3.4	3.3	.50	.80	.13	10.6
64	14M-6	G	12.62	---	.47	10.30	---	---	---	---	---	---	---	---	---
71	YB-51	G	16.89	---	.46	11.46	---	---	---	---	---	---	---	---	---
131	YB-16	G	14.59	4.04	---	---	---	---	---	---	---	---	---	---	---
		D	15.52	4.98	---	---	---	---	---	---	---	---	---	---	---
163	YB-37	G	17.43	3.76	.49	9.55	50.1	11.9	8.7	1.1	1.09	.52	.81	.02	21.2
		D	16.66	4.90	.15	5.39	55.4	16.2	5.3	2.3	1.68	.57	.88	.05	12.0
168	WR-50	G	21.04	3.60	.27	6.86	50.4	12.0	9.2	1.2	.80	.65	.73	.03	20.3
172	WR-49	G	17.97	4.02	.43	6.66	52.6	12.9	8.8	1.3	.88	.53	.71	.04	19.7
175	WR-48	G	15.07	3.30	.18	7.4	47.4	10.8	10.7	1.1	.86	.56	.66	.03	23.4
180	YB-46	G	16.40	---	.26	8.02	---	---	---	---	---	---	---	---	---
		D	15.79	---	.48	5.61	---	---	---	---	---	---	---	---	---
181	YB-42	G	18.35	3.82	.15	4.39	51.3	12.2	8.0	1.2	.77	.54	.72	.03	20.8
200	YB-44	G	14.80	---	.15	6.16	---	---	---	---	---	---	---	---	---
		D	14.66	---	.15	2.53	---	---	---	---	---	---	---	---	---
219	AL-64	G	11.95	3.46	.18	4.49	56.6	12.0	6.8	1.5	1.6	.27	.85	.06	15.9
		D	7.40	3.88	.18	2.31	61.9	13.2	4.8	1.8	1.8	.70	.94	.07	10.2

1/ Chemical analyses from files of the U.S. Geological Survey, Branch of Uranium and Thorium Resources, Denver, Colo. Assay values are weighted means.
2/ Locality numbers assigned by original investigators.
3/ G = Gassaway Member; D = Dowelltown Member.
4/ Total sulfur analysis is included in the loss on ignition value.

TABLE B-3. - Distribution of elements within units of the Chattanooga Shale compared to other shales[1/]

Elements[2/]	Gassaway Member, average values in percent			Dowelltown Member, average values in percent		Other shales,[4/] percent
	Top Black[3/]	Upper Gray[3/]	Middle Black[3/]	Middle Gray[3/]	Lower Black[3/]	
Mn	0.04	0.06	0.04	0.06	0.06	0.085
Cr	.01	.01	.01	.02	.02	.0090
Cs	.002	.002	.002	.002	.002	.0005
In	.004	.02	.005	.004	.009	.00001
Ca	.08	2.3	.2	.5	1.2	2.21
V	.08	.07	.08	.09	.1	.0130
Ce	.001	.001	.001	.001	.001	.0059
C	12.49	3.61	13.28	3.33	9.97	-
Pb	.02	.01	.02	.01	.02	.0020
Sn	.007	.003	.003	.003	.003	.00060
Zn	.06	.04	.06	.05	.06	.0095
Co	.02	.01	.04	.01	.01	.0019
Ni	.06	.04	.06	.04	.08	.0068
Ga	.01	.01	.01	.01	.01	.0019
Nb	.06	.07	.07	.08	.06	.0011
U	.0087	.0027	.0058	.0011	.0028	.00037
Ag	.0002	.0002	.0002	.0002	.0003	.000007
Ba	.02	.03	.03	.03	.02	.0580
B	.003	.006	.006	.01	.010	-
Be	.0002	.0002	.0002	.0002	.0004	.0003
Cu	.02	.02	.03	.03	.03	.0045
Ge	.001	.001	.002	.001	.001	.00016
Mo	.04	.01	.02	.01	.02	.00026
Ti	.9	.9	.9	.9	.9	.4600
Zr	.03	.03	.03	.03	.03	.0160
Na	.5	.5	.5	.5	.5	.9600
Li	.002	.002	.002	.003	.002	.0066
La	.005	.004	.003	.003	.004	.0092
Sr	.02	.02	.02	.02	.02	.0300
Mg	.5	.6	.6	1.0	1.2	1.5000
K	4.8	2.6	3.9	3.7	5.0	2.6600
Rb	.02	.08	.03	.1	.07	.0140

1/ Chattanooga Shale analyses from O'Neil, R. L. (23).
Analyses for units within the Chattanooga Shale are averages based on 61 randomly selected samples from two drill cores. Drill hole YB-19 (No. 124 this report), 59 samples. Drill hole NV-62 (No. 30 this report), two samples. Semiquantitative spectrochemical analysis by R. L. O'Neil.

2/ The following elements were not detected due to limits of equipment sensitivity (R. L. O'Neil): As, Y, Hf, Hg, Sc, Rh, Lu, Se, Tc, Cd, Bi, Th, Tl, Pd, Os, Rn, Tb, Sb, Pt, Ta, W.

3/ Unit names from R. L. O'Neil. Correspond to Upper, Middle, and Lower Gassaway, and Upper and Lower Dowelltown.

4/ Element distribution in other shales from Turekian, K. K., and K. H. Wedepohl (31).

TABLE B-4. - Comparison of thorium to uranium and oil in the Maury Formation and Chattanooga Shale[1/]

Locality No.		Unit[2/]	Thickness, feet	Thorium, percent	Uranium, percent	Oil, gal/ton
This report	Field					
28	NV-56	M	1.42	0.00115	0.0013	-
		G	9.67	.00082	.0056	7.7
		D	13.15	.00105	.0009	6.5
71	YB-51	G	16.89	.00076	.0050	-
163	YB-37	G	17.43	.00092	.0057	8.1
		D	16.66	.00114	.0019	4.1
168	WR-50	M	2.70	.00120	.0007	-
		G	21.04	.00103	.0070	1.9
		D	13.85	.00125	.0015	-
172	WR-49	M	2.57	.00130	.0003	-
		G	17.97	.00111	.0058	3.3
180	YB-46	G	16.40	.00072	.0066	-
		D	15.79	.00101	.0018	-
200	YB-44	G	14.80	.00074	.0065	5.0
		D	14.66	.00096	.0020	3.5
219	AL-64	G	11.95	.00084	.0044	.7
		D	7.40	.00106	.0019	1.2

1/ Assay values are weighted means. Thorium analyses from Brown (6). Uranium and oil values provided for comparison purposes and referenced in table A-1, appendix A.

2/ Unit designations: M, Maury Formation; G, Gassaway Member, and D, Dowelltown Member, Chattanooga Shale.

FIGURE B-1

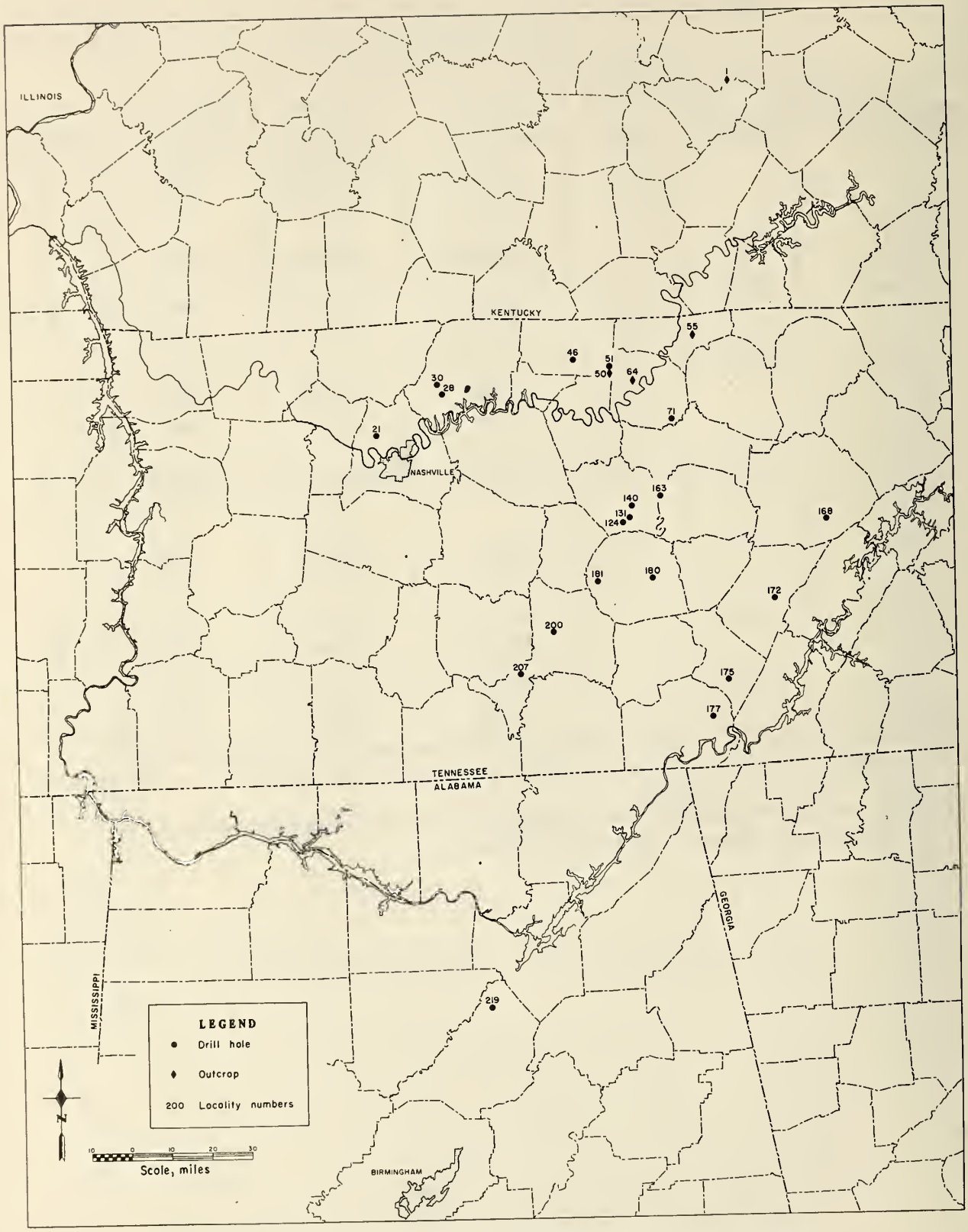

FIGURE B-1. - Sample localities in Tennessee and adjacent areas.

APPENDIX C.--RESULTS OF LAND DISTURBANCE MODEL

TABLE C-1. - Results of land disturbance model

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	SHALE TO BE MINED PER YEAR (TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
8	0.0045	65	40	585.16	3076.07	50000001.	8.00	384.5
			50	731.45	2460.86	40000000.	6.40	
			60	877.74	2050.71	33333334.	5.33	
			70	1024.03	1757.75	28571430.	4.57	
8	0.0050	65	40	650.18	2768.46	45000001.	7.20	384.5
			50	812.73	2214.77	36000000.	5.76	
			60	975.27	1845.64	30000001.	4.80	
			70	1137.82	1581.98	25714286.	4.11	
8	0.0055	65	40	715.20	2516.79	40909092.	6.55	384.5
			50	894.00	2013.43	32727273.	5.24	
			60	1072.80	1677.86	27272728.	4.36	
			70	1251.60	1438.16	23376624.	3.74	
8	0.0060	65	40	780.22	2307.05	37500000.	6.00	384.5
			50	975.27	1845.64	30000000.	4.80	
			60	1170.32	1538.04	25000000.	4.00	
			70	1365.38	1318.32	21428572.	3.43	
8	0.0065	65	40	845.23	2129.59	34615385.	5.54	384.5
			50	1056.54	1703.67	27692308.	4.43	
			60	1267.85	1419.73	23076924.	3.69	
			70	1479.16	1216.91	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	(TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
8	0.0045	70	40	630.17	2856.35	50000001.	8.00	357.0
			50	787.72	2285.08	40000000.	6.40	
			60	945.26	1904.23	33333334.	5.33	
			70	1102.81	1632.20	28571430.	4.57	
8	0.0050	70	40	700.19	2570.72	45000001.	7.20	357.0
			50	875.24	2056.57	36000001.	5.76	
			60	1050.29	1713.81	30000001.	4.80	
			70	1225.34	1468.98	25714286.	4.11	
8	0.0055	70	40	770.21	2337.02	40909092.	6.55	357.0
			50	962.77	1869.61	32727273.	5.24	
			60	1155.32	1558.01	27272728.	4.36	
			70	1347.87	1335.44	23376624.	3.74	
8	0.0060	70	40	840.23	2142.26	37500001.	6.00	357.0
			50	1050.29	1713.81	30000000.	4.80	
			60	1260.35	1428.18	25000001.	4.00	
			70	1470.41	1224.15	21428572.	3.43	
8	0.0065	70	40	910.25	1977.47	34615385.	5.54	357.0
			50	1137.82	1581.98	27692308.	4.43	
			60	1365.38	1318.32	23076923.	3.69	
			70	1592.94	1129.99	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	SHALE TO BE MINED PER YEAR (TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
8	0.0045	75	40	675.19	2665.93	50000001.	8.00	333.2
			50	843.98	2132.74	40000000.	6.40	
			60	1012.78	1777.29	33333334.	5.33	
			70	1181.58	1523.39	28571429.	4.57	
8	0.0050	75	40	750.21	2399.34	45000001.	7.20	333.2
			50	937.76	1919.47	36000001.	5.76	
			60	1125.31	1599.56	30000001.	4.80	
			70	1312.86	1371.05	25714286.	4.11	
8	0.0055	75	40	825.23	2181.21	40909092.	6.55	333.2
			50	1031.54	1744.97	32727273.	5.24	
			60	1237.84	1454.14	27272728.	4.36	
			70	1444.15	1246.41	23376624.	3.74	
8	0.0060	75	40	900.25	1999.45	37500001.	6.00	333.2
			50	1125.31	1599.56	30000001.	4.80	
			60	1350.37	1332.96	25000001.	4.00	
			70	1575.44	1142.54	21428572.	3.43	
8	0.0065	75	40	975.27	1845.64	34615385.	5.54	333.2
			50	1219.09	1476.51	27692308.	4.43	
			60	1462.91	1230.43	23076923.	3.69	
			70	1706.72	1054.65	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	SHALE TO BE MINED PER YEAR (TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
8	0.0045	80	40	720.20	2499.31	50000000.	8.00	312.4
			50	900.25	1999.45	40000000.	6.40	
			60	1080.30	1666.21	33333334.	5.33	
			70	1260.35	1428.18	28571429.	4.57	
8	0.0050	80	40	800.22	2249.38	45000001.	7.20	312.4
			50	1000.28	1799.50	36000000.	5.76	
			60	1200.33	1499.58	30000001.	4.80	
			70	1400.39	1285.36	25714286.	4.11	
8	0.0055	80	40	880.24	2044.89	40909092.	6.55	312.4
			50	1100.30	1635.91	32727274.	5.24	
			60	1320.37	1363.26	27272728.	4.36	
			70	1540.43	1168.51	23376624.	3.74	
8	0.0060	80	40	960.27	1874.48	37500000.	6.00	312.4
			50	1200.33	1499.58	30000001.	4.80	
			60	1440.40	1249.65	25000001.	4.00	
			70	1680.47	1071.13	21428572.	3.43	
8	0.0065	80	40	1040.29	1730.29	34615385.	5.54	312.4
			50	1300.36	1384.23	27692308.	4.43	
			60	1560.43	1153.53	23076924.	3.69	
			70	1820.50	988.74	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	(TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
8	0.0045	85	40	765.21	2352.29	50000001.	8.00	294.0
			50	956.51	1881.83	40000001.	6.40	
			60	1147.82	1568.19	33333334.	5.33	
			70	1339.12	1344.17	28571429.	4.57	
8	0.0050	85	40	850.24	2117.06	45000001.	7.20	294.0
			50	1062.79	1693.65	36000001.	5.76	
			60	1275.35	1411.37	30000001.	4.80	
			70	1487.91	1209.75	25714287.	4.11	
8	0.0055	85	40	935.26	1924.60	40909092.	6.55	294.0
			50	1169.07	1539.68	32727273.	5.24	
			60	1402.89	1283.07	27272728.	4.36	
			70	1636.70	1099.77	23376624.	3.74	
8	0.0060	85	40	1020.28	1764.22	37500000.	6.00	294.0
			50	1275.35	1411.37	30000000.	4.80	
			60	1530.42	1176.14	25000000.	4.00	
			70	1785.49	1008.12	21428572.	3.43	
8	0.0065	85	40	1105.31	1628.51	34615385.	5.54	294.0
			50	1381.63	1302.81	27692308.	4.43	
			60	1657.96	1085.67	23076924.	3.69	
			70	1934.29	930.58	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	(TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
11	0.0045	65	40	804.60	2237.14	50000001.	8.00	279.6
			50	1005.75	1789.71	40000000.	6.40	
			60	1206.90	1491.43	33333334.	5.33	
			70	1408.05	1278.37	28571429.	4.57	
11	0.0050	65	40	894.00	2013.43	45000001.	7.20	279.6
			50	1117.50	1610.74	36000001.	5.76	
			60	1341.00	1342.29	30000001.	4.80	
			70	1564.50	1150.53	25714286.	4.11	
11	0.0055	65	40	983.40	1830.39	40909092.	6.55	279.6
			50	1229.25	1464.31	32727273.	5.24	
			60	1475.10	1220.26	27272728.	4.36	
			70	1720.95	1045.94	23376624.	3.74	
11	0.0060	65	40	1072.80	1677.86	37500000.	6.00	279.6
			50	1341.00	1342.29	30000000.	4.80	
			60	1609.20	1118.57	25000000.	4.00	
			70	1877.39	958.78	21428572.	3.43	
11	0.0065	65	40	1162.20	1548.79	34615385.	5.54	279.6
			50	1452.75	1239.03	27692308.	4.43	
			60	1743.30	1032.53	23076924.	3.69	
			70	2033.84	885.02	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	(TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
11	0.0045	70	40	866.49	2077.35	50000001.	8.00	259.7
			50	1083.11	1661.88	40000001.	6.40	
			60	1299.73	1384.90	33333334.	5.33	
			70	1516.36	1187.06	28571429.	4.57	
11	0.0050	70	40	962.77	1869.61	45000001.	7.20	259.7
			50	1203.46	1495.69	36000001.	5.76	
			60	1444.15	1246.41	30000001.	4.80	
			70	1684.84	1068.35	25714286.	4.11	
11	0.0055	70	40	1059.04	1699.65	40909092.	6.55	259.7
			50	1323.80	1359.72	32727273.	5.24	
			60	1588.56	1133.10	27272728.	4.36	
			70	1853.33	971.23	23376624.	3.74	
11	0.0060	70	40	1155.32	1558.01	37500000.	6.00	259.7
			50	1444.15	1246.41	30000001.	4.80	
			60	1732.98	1038.67	25000000.	4.00	
			70	2021.81	890.29	21428572.	3.43	
11	0.0065	70	40	1251.60	1438.16	34615385.	5.54	259.7
			50	1564.50	1150.53	27692308.	4.43	
			60	1877.39	958.78	23076923.	3.69	
			70	2190.29	821.81	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	SHALE TO BE MINED PER YEAR (TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
11	0.0045	75	40	928.38	1938.86	50000001.	8.00	242.4
			50	1160.48	1551.09	40000000.	6.40	
			60	1392.57	1292.57	33333334.	5.33	
			70	1624.67	1107.92	28571429.	4.57	
11	0.0050	75	40	1031.54	1744.97	45000002.	7.20	242.4
			50	1289.42	1395.98	36000001.	5.76	
			60	1547.30	1163.31	30000001.	4.80	
			70	1805.19	997.13	25714287.	4.11	
11	0.0055	75	40	1134.69	1586.34	40909092.	6.55	242.4
			50	1418.36	1269.07	32727273.	5.24	
			60	1702.03	1057.56	27272728.	4.36	
			70	1985.71	906.48	23376624.	3.74	
11	0.0060	75	40	1237.84	1454.14	37500000.	6.00	242.4
			50	1547.30	1163.31	30000000.	4.80	
			60	1856.76	969.43	25000000.	4.00	
			70	2166.22	830.94	21428572.	3.43	
11	0.0065	75	40	1341.00	1342.29	34615385.	5.54	242.4
			50	1676.25	1073.83	27692308.	4.43	
			60	2011.49	894.86	23076923.	3.69	
			70	2346.74	767.02	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	(TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
11	0.0045	80	40	990.27	1817.68	50000001.	8.00	227.2
			50	1237.84	1454.14	40000000.	6.40	
			60	1485.41	1211.79	33333334.	5.33	
			70	1732.98	1038.67	28571429.	4.57	
11	0.0050	80	40	1100.30	1635.91	45000001.	7.20	227.2
			50	1375.38	1308.73	36000001.	5.76	
			60	1650.46	1090.61	30000001.	4.80	
			70	1925.53	934.81	25714286.	4.11	
11	0.0055	80	40	1210.34	1487.19	40909092.	6.55	227.2
			50	1512.92	1189.75	32727273.	5.24	
			60	1815.50	991.46	27272728.	4.36	
			70	2118.09	849.82	23376624.	3.74	
11	0.0060	80	40	1320.37	1363.26	37500001.	6.00	227.2
			50	1650.46	1090.61	30000000.	4.80	
			60	1980.55	908.84	25000000.	4.00	
			70	2310.64	779.01	21428572.	3.43	
11	0.0065	80	40	1430.40	1258.39	34615385.	5.54	227.2
			50	1788.00	1006.71	27692308.	4.43	
			60	2145.59	838.93	23076923.	3.69	
			70	2503.19	719.08	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	(TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
11	0.0045	85	40	1052.17	1710.76	50000000.	8.00	213.8
			50	1315.21	1368.60	40000000.	6.40	
			60	1578.25	1140.50	33333334.	5.33	
			70	1841.29	977.57	28571429.	4.57	
11	0.0050	85	40	1169.07	1539.68	45000001.	7.20	213.8
			50	1461.34	1231.74	36000000.	5.76	
			60	1753.61	1026.45	30000001.	4.80	
			70	2045.88	879.82	25714286.	4.11	
11	0.0055	85	40	1285.98	1399.71	40909092.	6.55	213.8
			50	1607.48	1119.77	32727273.	5.24	
			60	1928.97	933.14	27272728.	4.36	
			70	2250.47	799.83	23376624.	3.74	
11	0.0060	85	40	1402.89	1283.07	37500000.	6.00	213.8
			50	1753.61	1026.45	30000001.	4.80	
			60	2104.33	855.38	25000000.	4.00	
			70	2455.05	733.18	21428572.	3.43	
11	0.0065	85	40	1519.80	1184.37	34615385.	5.54	213.8
			50	1899.74	947.50	27692308.	4.43	
			60	2279.69	789.58	23076923.	3.69	
			70	2659.64	676.78	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	SHALE TO BE MINED PER YEAR (TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
14	0.0045	65	40	1024.03	1757.75	50000000.	8.00	219.7
			50	1280.04	1406.20	40000000.	6.40	
			60	1536.05	1171.84	33333334.	5.33	
			70	1792.06	1004.43	28571429.	4.57	
14	0.0050	65	40	1137.82	1581.98	45000001.	7.20	219.7
			50	1422.27	1265.58	36000001.	5.76	
			60	1706.72	1054.65	30000001.	4.80	
			70	1991.18	903.99	25714286.	4.11	
14	0.0055	65	40	1251.60	1438.16	40909092.	6.55	219.7
			50	1564.50	1150.53	32727273.	5.24	
			60	1877.39	958.78	27272728.	4.36	
			70	2190.29	821.81	23376624.	3.74	
14	0.0060	65	40	1365.38	1318.32	37500000.	6.00	219.7
			50	1706.72	1054.65	30000001.	4.80	
			60	2048.07	878.88	25000000.	4.00	
			70	2389.41	753.32	21428572.	3.43	
14	0.0065	65	40	1479.16	1216.91	34615385.	5.54	219.7
			50	1848.95	973.53	27692308.	4.43	
			60	2218.74	811.27	23076923.	3.69	
			70	2588.53	695.38	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	SHALE TO BE MINED PER YEAR (TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
14	0.0045	70	40	1102.81	1632.20	50000001.	8.00	204.0
			50	1378.51	1305.76	40000000.	6.40	
			60	1654.21	1088.13	33333334.	5.33	
			70	1929.91	932.69	28571429.	4.57	
14	0.0050	70	40	1225.34	1468.98	45000001.	7.20	204.0
			50	1531.67	1175.18	36000001.	5.76	
			60	1838.01	979.32	30000001.	4.80	
			70	2144.34	839.42	25714286.	4.11	
14	0.0055	70	40	1347.87	1335.44	40909092.	6.55	204.0
			50	1684.84	1068.35	32727274.	5.24	
			60	2021.81	890.29	27272728.	4.36	
			70	2358.78	763.11	23376624.	3.74	
14	0.0060	70	40	1470.41	1224.15	37500000.	6.00	204.0
			50	1838.01	979.32	30000000.	4.80	
			60	2205.61	816.10	25000000.	4.00	
			70	2573.21	699.51	21428572.	3.43	
14	0.0065	70	40	1592.94	1129.99	34615385.	5.54	204.0
			50	1991.18	903.99	27692308.	4.43	
			60	2389.41	753.32	23076924.	3.69	
			70	2787.65	645.71	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	SHALE TO BE MINED PER YEAR (TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
14	0.0045	75	40	1181.58	1523.39	50000000.	8.00	190.4
			50	1476.97	1218.71	40000000.	6.40	
			60	1772.37	1015.59	33333334.	5.33	
			70	2067.76	870.51	28571429.	4.57	
14	0.0050	75	40	1312.86	1371.05	45000001.	7.20	190.4
			50	1641.08	1096.84	36000001.	5.76	
			60	1969.30	914.03	30000001.	4.80	
			70	2297.51	783.46	25714286.	4.11	
14	0.0055	75	40	1444.15	1246.41	40909092.	6.55	190.4
			50	1805.19	997.13	32727273.	5.24	
			60	2166.22	830.94	27272728.	4.36	
			70	2527.26	712.23	23376624.	3.74	
14	0.0060	75	40	1575.44	1142.54	37500001.	6.00	190.4
			50	1969.30	914.03	30000001.	4.80	
			60	2363.15	761.69	25000001.	4.00	
			70	2757.01	652.88	21428572.	3.43	
14	0.0065	75	40	1706.72	1054.65	34615385.	5.54	190.4
			50	2133.40	843.72	27692308.	4.43	
			60	2560.08	703.10	23076924.	3.69	
			70	2986.76	602.66	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	(TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
14	0.0045	80	40	1260.35	1428.18	50000000.	8.00	178.5
			50	1575.44	1142.54	40000000.	6.40	
			60	1890.52	952.12	33333334.	5.33	
			70	2205.61	816.10	28571429.	4.57	
14	0.0050	80	40	1400.39	1285.36	45000001.	7.20	178.5
			50	1750.48	1028.29	36000001.	5.76	
			60	2100.58	856.91	30000001.	4.80	
			70	2450.68	734.49	25714286.	4.11	
14	0.0055	80	40	1540.43	1168.51	40909092.	6.55	178.5
			50	1925.53	934.81	32727273.	5.24	
			60	2310.64	779.01	27272728.	4.36	
			70	2695.75	667.72	23376624.	3.74	
14	0.0060	80	40	1680.47	1071.13	37500000.	6.00	178.5
			50	2100.58	856.91	30000001.	4.80	
			60	2520.70	714.09	25000000.	4.00	
			70	2940.81	612.08	21428572.	3.43	
14	0.0065	80	40	1820.50	988.74	34615385.	5.54	178.5
			50	2275.63	790.99	27692308.	4.43	
			60	2730.76	659.16	23076923.	3.69	
			70	3185.88	564.99	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	SHALE TO BE MINED PER YEAR (TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
14	0.0045	85	40	1339.12	1344.17	50000001.	8.00	168.0
			50	1673.90	1075.33	40000001.	6.40	
			60	2008.68	896.11	33333334.	5.33	
			70	2343.46	768.09	28571429.	4.57	
14	0.0050	85	40	1487.91	1209.75	45000001.	7.20	168.0
			50	1859.89	967.80	36000001.	5.76	
			60	2231.87	806.50	30000001.	4.80	
			70	2603.85	691.29	25714286.	4.11	
14	0.0055	85	40	1636.70	1099.77	40909092.	6.55	168.0
			50	2045.88	879.82	32727273.	5.24	
			60	2455.05	733.18	27272728.	4.36	
			70	2864.23	628.44	23376624.	3.74	
14	0.0060	85	40	1785.49	1008.12	37500000.	6.00	168.0
			50	2231.87	806.50	30000000.	4.80	
			60	2678.24	672.08	25000000.	4.00	
			70	3124.62	576.07	21428572.	3.43	
14	0.0065	85	40	1934.29	930.58	34615385.	5.54	168.0
			50	2417.86	744.46	27692308.	4.43	
			60	2901.43	620.38	23076923.	3.69	
			70	3385.00	531.76	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	(TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
17	0.0045	65	40	1243.47	1447.56	50000001.	8.00	180.9
			50	1554.34	1158.05	40000000.	6.40	
			60	1865.20	965.04	33333334.	5.33	
			70	2176.07	827.18	28571429.	4.57	
17	0.0050	65	40	1381.63	1302.81	45000001.	7.20	180.9
			50	1727.04	1042.25	36000001.	5.76	
			60	2072.45	868.54	30000001.	4.80	
			70	2417.86	744.46	25714287.	4.11	
17	0.0055	65	40	1519.80	1184.37	40909092.	6.55	180.9
			50	1899.74	947.50	32727273.	5.24	
			60	2279.69	789.58	27272728.	4.36	
			70	2659.64	676.78	23376624.	3.74	
17	0.0060	65	40	1657.96	1085.67	37500000.	6.00	180.9
			50	2072.45	868.54	30000000.	4.80	
			60	2486.94	723.78	25000000.	4.00	
			70	2901.43	620.38	21428572.	3.43	
17	0.0065	65	40	1796.12	1002.16	34615385.	5.54	180.9
			50	2245.15	801.73	27692308.	4.43	
			60	2694.18	668.11	23076923.	3.69	
			70	3143.21	572.66	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	SHALE TO BE MINED PER YEAR (TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
17	0.0045	70	40	1339.12	1344.17	50000001.	8.00	168.0
			50	1673.90	1075.33	40000001.	6.40	
			60	2008.68	896.11	33333334.	5.33	
			70	2343.46	768.09	28571429.	4.57	
17	0.0050	70	40	1487.91	1209.75	45000001.	7.20	168.0
			50	1859.89	967.80	36000001.	5.76	
			60	2231.87	806.50	30000001.	4.80	
			70	2603.85	691.29	25714286.	4.11	
17	0.0055	70	40	1636.70	1099.77	40909092.	6.55	168.0
			50	2045.88	879.82	32727273.	5.24	
			60	2455.05	733.18	27272728.	4.36	
			70	2864.23	628.44	23376624.	3.74	
17	0.0060	70	40	1785.49	1008.12	37500000.	6.00	168.0
			50	2231.87	806.50	30000000.	4.80	
			60	2678.24	672.08	25000000.	4.00	
			70	3124.62	576.07	21428572.	3.43	
17	0.0065	70	40	1934.29	930.58	34615385.	5.54	168.0
			50	2417.86	744.46	27692308.	4.43	
			60	2901.43	620.38	23076923.	3.69	
			70	3385.00	531.76	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	(TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
17	0.0045	75	40	1434.77	1254.55	50000001.	8.00	156.8
			50	1793.47	1003.64	40000000.	6.40	
			60	2152.16	836.37	33333334.	5.33	
			70	2510.85	716.89	28571429.	4.57	
17	0.0050	75	40	1594.19	1129.10	45000001.	7.20	156.8
			50	1992.74	903.28	36000001.	5.76	
			60	2391.29	752.73	30000001.	4.80	
			70	2789.83	645.20	25714286.	4.11	
17	0.0055	75	40	1753.61	1026.45	40909092.	6.55	156.8
			50	2192.01	821.16	32727273.	5.24	
			60	2630.42	684.30	27272728.	4.36	
			70	3068.82	586.54	23376624.	3.74	
17	0.0060	75	40	1913.03	940.92	37500000.	6.00	156.8
			50	2391.29	752.73	30000000.	4.80	
			60	2869.54	627.28	25000001.	4.00	
			70	3347.80	537.67	21428572.	3.43	
17	0.0065	75	40	2072.45	868.54	34615385.	5.54	156.8
			50	2590.56	694.83	27692308.	4.43	
			60	3108.67	579.03	23076924.	3.69	
			70	3626.79	496.31	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	SHALE TO BE MINED PER YEAR (TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
17	0.0045	80	40	1530.42	1176.14	50000001.	8.00	147.0
			50	1913.03	940.92	40000000.	6.40	
			60	2295.64	784.10	33333334.	5.33	
			70	2678.24	672.08	28571429.	4.57	
17	0.0050	80	40	1700.47	1058.53	45000001.	7.20	147.0
			50	2125.59	846.82	36000001.	5.76	
			60	2550.71	705.69	30000001.	4.80	
			70	2975.82	604.87	25714287.	4.11	
17	0.0055	80	40	1870.52	962.30	40909092.	6.55	147.0
			50	2338.15	769.84	32727273.	5.24	
			60	2805.78	641.53	27272728.	4.36	
			70	3273.41	549.89	23376624.	3.74	
17	0.0060	80	40	2040.57	882.11	37500000.	6.00	147.0
			50	2550.71	705.69	30000000.	4.80	
			60	3060.85	588.07	25000000.	4.00	
			70	3570.99	504.06	21428572.	3.43	
17	0.0065	80	40	2210.61	814.25	34615385.	5.54	147.0
			50	2763.27	651.40	27692308.	4.43	
			60	3315.92	542.84	23076924.	3.69	
			70	3868.57	465.29	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	SHALE TO BE MINED PER YEAR (TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
17	0.0045	85	40	1626.08	1106.96	50000001.	8.00	138.4
			50	2032.59	885.57	40000000.	6.40	
			60	2439.11	737.97	33333334.	5.33	
			70	2845.63	632.55	28571429.	4.57	
17	0.0050	85	40	1806.75	996.26	45000001.	7.20	138.4
			50	2258.44	797.01	36000001.	5.76	
			60	2710.13	664.18	30000001.	4.80	
			70	3161.81	569.29	25714286.	4.11	
17	0.0055	85	40	1987.43	905.69	40909092.	6.55	138.4
			50	2484.28	724.56	32727273.	5.24	
			60	2981.14	603.80	27272728.	4.36	
			70	3477.99	517.54	23376624.	3.74	
17	0.0060	85	40	2168.10	830.22	37500000.	6.00	138.4
			50	2710.13	664.18	30000000.	4.80	
			60	3252.15	553.48	25000000.	4.00	
			70	3794.18	474.41	21428572.	3.43	
17	0.0065	85	40	2348.78	766.36	34615385.	5.54	138.4
			50	2935.97	613.09	27692308.	4.43	
			60	3523.16	510.90	23076923.	3.69	
			70	4110.36	437.92	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	SHALE TO BE MINED PER YEAR (TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
20	0.0045	65	40	1462.91	1230.43	50000001.	8.00	153.8
			50	1828.63	984.34	40000000.	6.40	
			60	2194.36	820.29	33333334.	5.33	
			70	2560.08	703.10	28571429.	4.57	
20	0.0050	65	40	1625.45	1107.39	45000001.	7.20	153.8
			50	2031.81	885.91	36000001.	5.76	
			60	2438.18	738.26	30000001.	4.80	
			70	2844.54	632.79	25714286.	4.11	
20	0.0055	65	40	1788.00	1006.71	40909092.	6.55	153.8
			50	2234.99	805.37	32727273.	5.24	
			60	2681.99	671.14	27272728.	4.36	
			70	3128.99	575.27	23376624.	3.74	
20	0.0060	65	40	1950.54	922.82	37500000.	6.00	153.8
			50	2438.18	738.26	30000001.	4.80	
			60	2925.81	615.21	25000001.	4.00	
			70	3413.45	527.33	21428572.	3.43	
20	0.0065	65	40	2113.09	851.84	34615385.	5.54	153.8
			50	2641.36	681.47	27692308.	4.43	
			60	3169.63	567.89	23076923.	3.69	
			70	3697.90	486.76	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	SHALE TO BE MINED PER YEAR (TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
20	0.0045	70	40	1575.44	1142.54	50000001.	8.00	142.8
			50	1969.30	914.03	40000000.	6.40	
			60	2363.15	761.69	33333334.	5.33	
			70	2757.01	652.88	28571429.	4.57	
20	0.0050	70	40	1750.48	1028.29	45000001.	7.20	142.8
			50	2188.11	822.63	36000001.	5.76	
			60	2625.73	685.52	30000001.	4.80	
			70	3063.35	587.59	25714286.	4.11	
20	0.0055	70	40	1925.53	934.81	40909092.	6.55	142.8
			50	2406.92	747.84	32727273.	5.24	
			60	2888.30	623.20	27272728.	4.36	
			70	3369.68	534.17	23376623.	3.74	
20	0.0060	70	40	2100.58	856.91	37500000.	6.00	142.8
			50	2625.73	685.52	30000001.	4.80	
			60	3150.87	571.27	25000000.	4.00	
			70	3676.02	489.66	21428572.	3.43	
20	0.0065	70	40	2275.63	790.99	34615384.	5.54	142.8
			50	2844.54	632.79	27692308.	4.43	
			60	3413.45	527.33	23076923.	3.69	
			70	3982.35	451.99	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	(TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
20	0.0045	75	40	1687.97	1066.37	50000000.	8.00	133.3
			50	2109.96	853.10	40000000.	6.40	
			60	2531.95	710.91	33333334.	5.33	
			70	2953.94	609.36	28571429.	4.57	
20	0.0050	75	40	1875.52	959.73	45000001.	7.20	133.3
			50	2344.40	767.79	36000000.	5.76	
			60	2813.28	639.82	30000001.	4.80	
			70	3282.16	548.42	25714286.	4.11	
20	0.0055	75	40	2063.07	872.49	40909092.	6.55	133.3
			50	2578.84	697.99	32727274.	5.24	
			60	3094.61	581.66	27272728.	4.36	
			70	3610.37	498.56	23376624.	3.74	
20	0.0060	75	40	2250.62	799.78	37500000.	6.00	133.3
			50	2813.28	639.82	30000001.	4.80	
			60	3375.93	533.19	25000001.	4.00	
			70	3938.59	457.02	21428572.	3.43	
20	0.0065	75	40	2438.18	738.26	34615385.	5.54	133.3
			50	3047.72	590.61	27692308.	4.43	
			60	3657.26	492.17	23076924.	3.69	
			70	4266.81	421.86	19780220.	3.16	

TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	(TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
20	0.0045	80	40	1800.50	999.72	50000001.	8.00	125.0
			50	2250.62	799.78	40000000.	6.40	
			60	2700.75	666.48	33333334.	5.33	
			70	3150.87	571.27	28571429.	4.57	
20	0.0050	80	40	2000.55	899.75	45000001.	7.20	125.0
			50	2500.69	719.80	36000001.	5.76	
			60	3000.83	599.83	30000001.	4.80	
			70	3500.97	514.14	25714286.	4.11	
20	0.0055	80	40	2200.61	817.96	40909092.	6.55	125.0
			50	2750.76	654.36	32727273.	5.24	
			60	3300.91	545.30	27272728.	4.36	
			70	3851.07	467.40	23376624.	3.74	
20	0.0060	80	40	2400.66	749.79	37500000.	6.00	125.0
			50	3000.83	599.83	30000000.	4.80	
			60	3601.00	499.86	25000000.	4.00	
			70	4201.16	428.45	21428572.	3.43	
20	0.0065	80	40	2600.72	692.12	34615385.	5.54	125.0
			50	3250.90	553.69	27692308.	4.43	
			60	3901.08	461.41	23076924.	3.69	
			70	4551.26	395.49	19780220.	3.16	

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TABLE C-1. - Results of land disturbance model--Continued

THICKNESS OF BED (FEET)	URANIUM CONTENT (PERCENT)	MINING RECOVERY (PERCENT)	PROCESSING RECOVERY (PERCENT)	URANIUM RECOVERABLE PER ACRE (POUNDS)	SHALE TO BE MINED PER YEAR (ACRES)	(TONS)	MINING OPERATIONS REQUIRED	ACRES PER YEAR TO BE MINED PER OPERATION)
20	0.0045	85	40	1913.03	940.92	50000001.	8.00	117.6
			50	2391.29	752.73	40000000.	6.40	
			60	2869.54	627.28	33333334.	5.33	
			70	3347.80	537.67	28571429.	4.57	
20	0.0050	85	40	2125.59	846.82	45000001.	7.20	117.6
			50	2656.99	677.46	36000001.	5.76	
			60	3188.38	564.55	30000001.	4.80	
			70	3719.78	483.90	25714287.	4.11	
20	0.0055	85	40	2338.15	769.84	40909092.	6.55	117.6
			50	2922.68	615.87	32727273.	5.24	
			60	3507.22	513.23	27272728.	4.36	
			70	4091.76	439.91	23376624.	3.74	
20	0.0060	85	40	2550.71	705.69	37500000.	6.00	117.6
			50	3188.38	564.55	30000000.	4.80	
			60	3826.06	470.46	25000000.	4.00	
			70	4463.74	403.25	21428571.	3.43	
20	0.0065	85	40	2763.27	651.40	34615385.	5.54	117.6
			50	3454.08	521.12	27692308.	4.43	
			60	4144.90	434.27	23076923.	3.69	
			70	4835.71	372.23	19780220.	3.16	

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